IN TWO SECTIONS—SECTION ONE

# MECHANICAL ENGINEERING

## THE JOURNAL OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

## A. S. M. E. SPRING MEETING

## ST. LOUIS, MAY 24 TO 27

## MAY 1920

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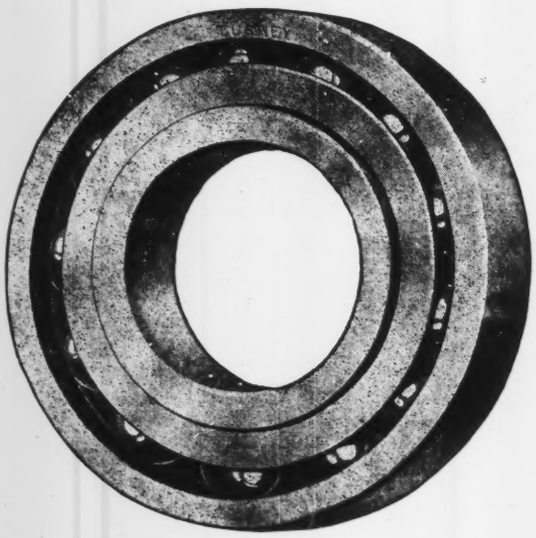

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# Mechanical Engineering

*The Journal of The American Society of Mechanical Engineers*

VOLUME 42 MAY, 1920 NUMBER 5

## TABLE OF CONTENTS

Aeronautic Instruments, M. D. Hersey ..... 263
The Rectilinear Flight of Aeroplanes, A. Rateau ..... 268
River Transportation in the Mississippi Valley, E. W. Schadek ..... 270
The Separation of Dissolved Gases From Water, J. R. McDermet ..... 273
A Stoker for Burning Eastern Coals, L. R. Stowe ..... 279
Locomotive Feedwater Heating, T. C. McBride ..... 285
Efficiency of Natural Gas Used in Domestic Service, R. F. Earhart ..... 287
Engineering Survey (Review of Periodicals) ..... 289
Engineering Research ..... 300
Work of the Boiler Code Committee ..... 302
Correspondence ..... 303
Editorial Notes: ..... 306

Meeting in Memory of Andrew Carnegie—John Fritz Medal—American Railway Engineering Association Joins Engineering Council—National Chamber of Commerce to Vote on Department of Public Works—Putting the Technic in the Technical Education—The Outdoor Power Plant—A New Development in Marine Propulsion—The Measurement of Minute Motion—New Engineering Periodical in Three Languages

A. S. M. E. Spring Meeting at St. Louis ..... 309
John Alfred Brashear ..... 311
Government Activities in Engineering ..... 313
News of the Engineering Societies ..... 315
Library Notes and Book Reviews ..... 317
The Engineering Index ..... 1*a*
A. S. M. E. Affairs (Section Two) ..... 73–88

ADVERTISING SECTION:

Display Advertisements ..... 2*b*
Consulting Engineers ..... 118
Directory of Engineering Colleges ..... 122
Classified Advertisements ..... 125
Classified List of Mechanical Equipment ..... 126
Alphabetical List of Advertisers ..... 144

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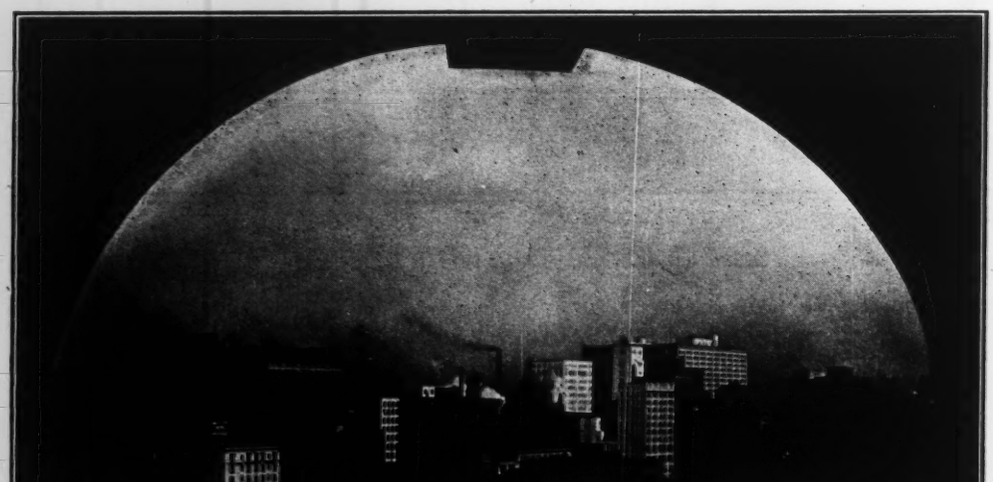

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Further details of the meeting will be found on pages 309 and 310.

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MECHANICAL ENGINEERING

THE JOURNAL OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

Volume 42 May 1920 Number 5

# Aeronautic Instruments

## A Paper on the General Principles of Their Construction, Testing and Use, Based on the Work of the Aeronautic Instruments Section of the Bureau of Standards

By MAYO D. HERSEY,[1] WASHINGTON, D. C.

*This paper, which is a contribution from the Aeronautic Instruments Section of the National Bureau of Standards, affords a brief sketch of the general principles of such instruments. The discussion takes up successively matters relating to the construction, the testing, and the practical use of instruments for aircraft. In each case principles rather than details are emphasized. In a few instances particular instruments are described or the results of particular investigations stated, in order to illustrate the principle involved. The paper, however, does not pretend to serve as a final or comprehensive report on the subject.*

*That the general field of aeronautic instruments is a less familiar one to the engineer at large than it logically ought to be, is probably due to the confidential character of the work which has gone forward during the war. Now that attention is again directed to civilian aeronautics the subject of instruments takes on great importance for two chief reasons: first, because the efficiency and safety of air navigation, especially in clouds, depend on the reliability of the instruments which are used; and second, because the whole future development of aeronautic engineering rests upon the measurement of aircraft performance, which requires suitable instruments of precision.*

THE life cycle of any aeronautic instrument starts with the recognition of some distinct physical measurement that has to be made in flight; then, broadly speaking, it passes through the three main stages of construction, testing, and use; and ends by revealing the need for some particular improvement or new development, at which point the cycle begins over again.

As a convenient way of arranging the available information, we will consider in succession these different stages or processes, emphasizing only the general principles involved, but illustrating the latter by their application to particular instruments such as the aneroid barometer or tachometer.

### 1 CONSTRUCTION OF INSTRUMENTS

In classifying instruments with regard to the purpose for which they are needed a fundamental distinction may be drawn between service instruments and experimental instruments. Service instruments have to be light and rugged, fool-proof, and reliable under all conditions of flight, and must not occupy too much space in the cockpit. Experimental instruments must be extremely accurate and the self-recording feature is desirable.

A further distinction may be drawn between instruments for balloon and airship use and those for airplanes. Historically, instruments for lighter-than-air craft were the first to be developed; but owing to the more extensive use of airplanes during the war, the scientific elaboration of airplane instruments stands now far in advance of airship instruments. The chief characteristics of airship instruments are the relatively lower range of speed and altitude over which the mechanism has to function accurately, and the correspondingly weaker forces available to operate the movement. In addition, there are some extra instruments needed on airships, for measuring conditions relating to the air and hydrogen supply.

Finally, all aircraft instruments may be classified with respect to the nature of the measurement made. From this viewpoint the most important groups are: (1) altitude instruments; (2) speed indicators; (3) direction indicators; (4) tachometers; (5) gasoline indicators; (6) thermometers and pressure gages for the power plant; (7) timepieces; (8) oxygen apparatus; and (9) additional instruments for lighter-than-air craft.

#### Altitude Instruments

Taking up these nine groups in order, altitude instruments, broadly considered, may be regarded as covering the following species:

*a* Altimeters
*b* Barographs
*c* Thermographs and aerographs
*d* Statoscopes
*e* Rate-of-climb indicators
*f* Night altitude indicators.

The altimeter is in principle a common aneroid barometer with a movable altitude scale instead of a fixed pressure scale. For airplane use, however, the aneroid has to be made uncommonly well; otherwise the instrument will have serious errors caused by the peculiar conditions of flight, and the pointer may vibrate so much that it can hardly be read.

A typical altimeter is seen in the upper left-hand part of the instrument board picture, Fig. 1. The elements of its construction are probably familiar, comprising a stiff steel spring coupled to a thin corrugated-metal vacuum box, together with a delicate transmission mechanism which multiplies the movement of the box. A dilation or contraction of the box only 0.002 or 0.003 in. causes a motion of 1 in. at the tip of the pointer. Various minor adjustments are provided, and usually a bimetallic bar forms part of the lever system, serving in some measure to compensate for the influence of temperature.

Barographs usually contain a tier of vacuum boxes, one on top of another from two to five in number, with a pair of steel springs inside each box. The multiplying factor of the transmission mechanism is decidedly less than in altimeters, so that the pen arm has correspondingly greater power for tracing a firm ink line on the revolving chart.

Thermographs are intended for recording the temperature of the atmosphere at different altitudes. They have been built both with bimetallic elements and with delicate Bourdon tubes containing mercury or ether. Aerographs are combination recording instruments comprising hair hygrometers for humidity determination along with the barometric and thermometric elements.

Abstract of a paper to be presented at the Spring Meeting, St. Louis, May 24 to 27, 1920, of The American Society of Mechanical Engineers. Advance copies of the complete paper may be obtained gratis upon application. All papers are subject to revision.

[1] Chief, Aeronautics Instrument Section, U. S. Bureau of Standards.

Statoscopes serve to tell whether a balloon or airship is slightly ascending or descending. They are remarkably sensitive, too much so to be of much use on airplanes. The statoscope in its simplest form is a thermally insulated vessel of air, connected to the external atmosphere by a glass tube containing a drop of red liquid which moves freely one way or the other in response to any minute change of external pressure.

Rate-of-climb indicators give a direct reading of the vertical speed in feet per minute. The most usual types are based upon the pressure difference set up between the two ends of a capillary tube connecting a thermally insulated air container with the external atmosphere. What is actually observed is the manometer indication of that differential pressure.

The night altitude indicator is an optical projection instrument of the range-finder type, particularly valuable for seaplanes flying low over the water.

### Speed Indicators

The pressure type of air-speed indicator shows the impact pressure of the air due to the motion of the aircraft and so enables the pilot to keep above his stalling speed and below the danger point due to excessive speed. Such instruments consist of two parts: the indicator proper on the instrument board in the cockpit (see Fig. 1), and a pressure head mounted out on some strut where it will catch the full force of the undisturbed atmosphere going by. The indicator part measures the differential pressure generated by the pressure head and transmitted to it through some length of tubing. Liquid manometers were used for the indicator early in the war, but later were superseded by various diaphragm constructions. Not only corrugated metal diaphragms, but even rubber and doped silk have been found satisfactory for this purpose.

The pitot tube and venturi tube have been tried out in a great variety of forms as pressure heads for air-speed indicators. A combination of the two gives the greatest differential pressure and was adopted in this country in preference to the pitot tube, in order to accelerate production of indicator mechanisms during the war.

Air-speed indicators of the anemometer type (or true air-speed type) are usually based on some rotating-vane or Robinson cup principle and connected, either directly or through electric transmission, with a tachometer movement.

Absolute or ground-speed indicators have been successfully made in the visual type which gives its result by combining an observation of the angular velocity of the line of sight with a knowledge of the altitude.

### Direction Indicators

The third general group, direction indicators, may be subdivided as follows:

*a* Compasses and turn indicators
*b* Inclinometers and banking indicators
*c* Angle-of-attack indicators
*d* Side-slip or yaw indicators
*e* Drift indicators
*f* Course-finding instruments.

Compasses may conceivably be either magnetic or gyroscopic, but the latter have not yet been successfully developed for airplanes. Magnetic compasses in common use are of the short-period type. Turn indicators have been made in both aerodynamic and gyroscopic forms. The former type measures the differential pressure between two static heads placed one at each wing tip. It is therefore a purely atmospheric instrument which might read zero if the aircraft were resting in a large portion of the atmosphere itself undergoing rotation. The gyroscopic forms show absolute rotation: one type is a very sensitive indicator showing whether the aircraft is or is not turning, and whether to the right or left, while the other type is somewhat less sensitive but actually measuring the rate of turning.

Inclinometers are to be distinguished from banking indicators in that they measure the inclination of the aircraft to the ground, while banking indicators show only the departure of the aircraft from the proper banking position. Gyroscopic inclinometers are usually of the long-period pendulum type. They function as a simple pendulum several thousand feet long, and so are free from the effects of transient accelerations, but not from persistent acceleration in the same direction. The most common inclinometers are liquid-filled tubes in the form of a large, triangular closed

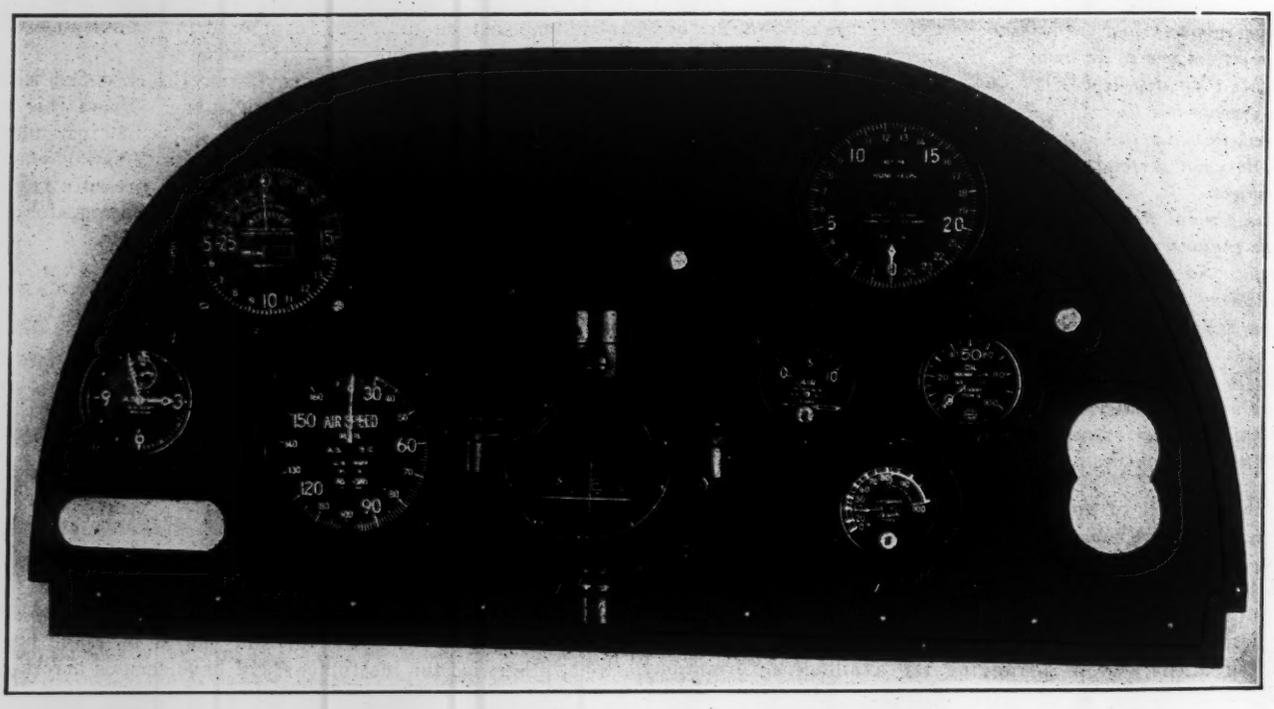


Fig. 1 Typical Airplane Instrument Board, Showing Altimeter, Timepiece, Air-Speed Indicator, Compass, Tachometer, Pressure Gages, and Radiator Thermometer

circuit, and are used for fore-and-aft observations. The commonest form of banking indicator is a modification of the familiar spirit level, bent into an arc of about 20 deg. each side of the zero. Mechanical pendulum types also are in use.

Angle-of-attack indicators show the angle between the wing chord, say, and the direction of motion. Both weather-vane and differential pressure types have been used, the latter like the side-slip indicator below.

Side-slip or yaw indicators show whether the aircraft is heading exactly in the direction of motion (relative to the atmosphere) or not. It operates by the differential pressure set up between symmetrically placed openings on the two sides of a sphere, attached to some strut so as to head directly forward. The two openings are connected to the two sides of a diaphragm movement with dial and pointer.

Drift indicators show the speed of drift compared to the speed of advance and involve the rotation of some reference line by the observer until it is parallel to the apparent trajectory of objects going by on the ground.

Course-finding instruments are merely mechanical devices for determining the course and distance made good, by reference to data already available.

### Tachometers

Tachometers constitute the fourth general group. All the various types serve for the sole purpose of indicating the revolutions per unit time of the propeller shaft, with the exception of one instrument which indicates also the angular acceleration of the propeller shaft, that is, its rate of speeding up or of slowing down. The diverse types of construction may be subdivided respectively as: Chronometric; centrifugal; magnetic; electric; air-viscosity and air-pump; and liquid.

The chronometric or clockwork type, the most accurate but most complicated, actually counts the number of revolutions in a fixed time.

The centrifugal type, most commonly used on aircraft, works on the principle of the change which takes place in the position of a revolving mass due to centrifugal force acting against the restoring force of a spring.

The magnetic type operates by the rotation of a permanent magnet near an electrically conducting disk which is mounted on the pointer spindle and controlled by a spring.

The electric type consists of a magneto, geared to the engine shaft, which transmits the resulting voltage to a millivoltmeter graduated to read revolutions per minute.

The air-viscosity type is similar to a torsion viscosimeter, measuring the product of viscosity by speed of rotation. Here the viscosity of the fluid, air, is so nearly a constant that the deflection of the spring and pointer is almost directly proportional to the speed of rotation. The air-pump type is based on the force of impact of the air against a movable vane resisted by a spring; the pump is geared to the engine shaft so that the deflection depends on the speed of rotation.

The liquid type involves the observation of the maximum height of a liquid column or deflection of Bourdon gage which can be maintained by a centrifugal pump geared to the engine shaft. By comparing the height of this column with that of a similar one heavily damped an indication of angular acceleration is also obtained.

### Gasoline Indicators

Gasoline indicators, the fifth group, comprise, broadly speaking, depth gages and flow meters. Depth gages show the available supply and are of two types, those based on a simple float principle and those which measure the hydrostatic pressure near the bottom of the tank. Flow meters show the rate of consumption of gasoline at any instant. They have been based on the venturi principle and also on the principle of utilizing the force of impact of the stream of liquid against a movable element resisted by a spring or by gravity.

### Thermometers and Pressure Gages

The sixth group comprises thermometers and pressure gages for the radiator, the lubrication system, and the gasoline tank, respectively. These thermometers are of the long-distance transmission type with liquid-filled or vapor-filled bulbs. The indicator movement, installed in the cockpit, consists essentially of a Bourdon tube element, as do also the air and oil pressure gages.

### Timepieces

The seventh group, timepieeces, presents no great novelty aside from the reversing stop watches used in connection with certain bomb sights; but they have to be rugged enough to withstand airplane service and provided with suitable dials.

### Oxygen Apparatus

Oxygen apparatus for the aviator (group 8) may be either of the compressed-oxygen, liquid, or chemical type. Only the first has been put into regular use in this country. These outfits are provided with automatic regulators which control the flow of oxygen from the storage tank to the aviator's breathing attachment. The regulators are designed to deliver an amount of oxygen which increases at the higher altitudes in accordance with a prescribed formula. The mechanism is operated by diaphragms. An example of such a regulator is shown in Fig. 2.

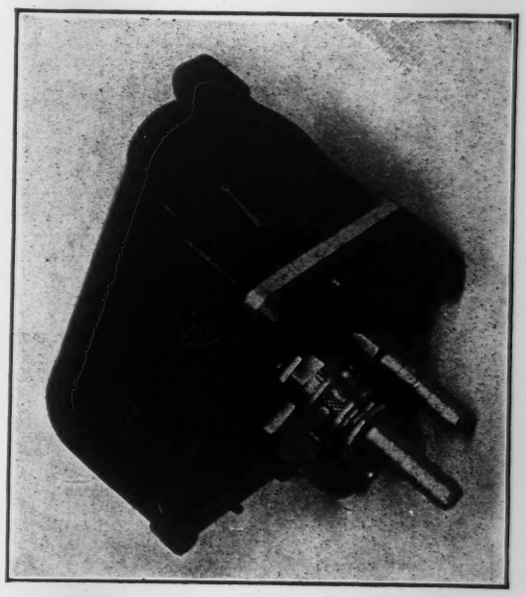

Fig. 2 Aviator's Oxygen Regulator

### Balloon and Airship Equipment

The ninth and last group comprises balloon and airship equipment not already included among the foregoing. Special pressure gages are made for indicating the amount of water ballast carried. Delicate manometers are made for measuring the air pressure in the balloonetts and the hydrogen pressure in the envelope; liquid types have been used, but sensitive diaphragms are better. Electric-resistance thermometers are used to indicate the temperature of the gas in the envelope. Hydrogen detectors based on osmotic pressure action are valuable for locating leaks.

### Design, Development and Production

The design of aeronautic instruments is at present almost wholly on a cut-and-try basis. The Bureau of Standards has made some progress, however, in placing instrument design on a rational basis. Consideration has been given to such general problems as: the stiffness of elastic systems where two bodies such as a spring and diaphragm are coupled together; the effects of temperature and elastic lag on coupled systems; bimetallic bars for temperature compensation; the balance of

moving parts to resist angular acceleration and vibration; the securing of a uniform scale by suitable design of transmission mechanism; and the treatment of aerodynamic problems and the general action of damping fluids by the method of dimensions described before this Society by Dr. Buckingham at the Buffalo meeting in 1915 in his paper on Model Experiments. There is hardly space here even to outline those results, which it is hoped may form the substance of later communications.

Experimental development has to follow the preliminary design of an instrument before it can be put into quantity production. Among the recent development projects of the Aeronautic Instruments Section at the Bureau of Standards may be mentioned the following, several of which were undertaken at the request of the Air Service or the National Advisory Committee for Aeronautics:

*a* The conversion of barographs from a low-altitude to a high-altitude range, together with the elimination of ink.

*b* The conversion of altimeters from an altitude scale to a pressure scale, to adapt them for aircraft performance testing. Improvements were also made in the method of mounting the main spring of commercial altimeters to diminish the observed differences between readings with increasing and decreasing altitudes.

*c* The development of a precision altimeter with a large dial giving a ¼-in. movement of the pointer for each 100 ft. of altitude, a special design being made for the elastic system to diminish elastic lag.

*d* The development of a direct-reading rate-of-climb indicator based on the capillary-tube-leak principle, with the use of a liquid entirely dispensed with through the use of sensitive diaphragms.

*e* Development of a reduced scale working model of a proposed gyro-stabilizer on the long-period pendulum principle, possessing mechanical features of extreme simplicity.

*f* The application of the moving-picture camera for securing a record of instrument readings during the performance test of an aircraft in flight. The whole outfit—instruments, illumination, camera and timing system—forms a unit which takes the place of the human observer in the airplane.

*g* A working model of a type of dynamical ground-speed indicator which would become available if there existed a suitable gyro-stabilizer to hold it horizontal. This model consists of a large steel ball free to roll back and forth in a glass tube filled with a viscous liquid. It can be shown mathematically that if the fluid resistance is directly proportional to the speed of the ball through the tube, while the tube is held in a horizontal fore-and-aft position, then the displacement of the ball at any instant from its initial position in the tube is directly proportional to the absolute ground speed of the aircraft.

The development work on any given model of an instrument must be dropped and the design rigidly fixed before quantity production can be efficiently carried on. In this country the quality of products made in quantity has to be artificially held up to standard by means of specifications and inspection. This situation is not so commonly met with abroad, especially in France, where every individual involved, from the mechanic in the shop up to the head of the concern, takes a professional artistic pride in the quality of his output. This difference is not the fault of the American manufacturer, and there are some advantages in our system, yet the fact remains; and this spectacle of successful instrument production without specifications formed one of the most astonishing impressions which the writer gathered from his trip to Europe during the war.

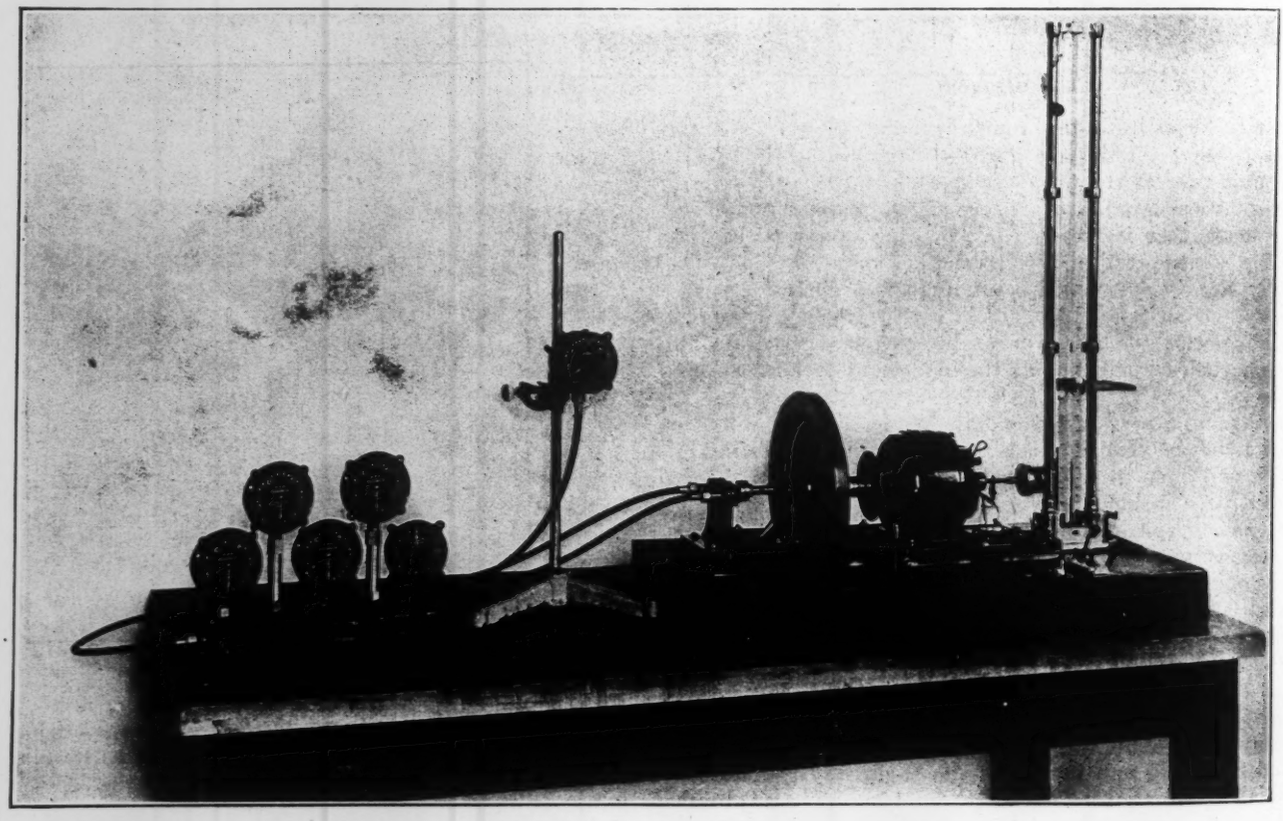

FIG. 3 TESTING OUTFIT FOR AIRPLANE TACHOMETERS

## 2 TESTING OF INSTRUMENTS

The testing of any aeronautic instrument consists in a direct comparison with some standard, the instrument being operated over its full scale; the whole procedure should then be repeated under different conditions varying in flight. The most important of these conditions are:

*a* Extreme low temperatures
*b* Change in pressure or density of air
*c* Acceleration and inclination
*d* Vibration
*e* Time elapsed during the flight.

A typical installation of testing apparatus, in this instance for the testing of tachometers, is shown in Fig. 3. The results of such a test are ordinarily given out in the form of tables or curves showing the correction of the instrument from point to point of its scale. By the correction is meant the amount that has to be added algebraically to the reading of the instrument in order to give the true value of the quantity measured. Typical correction plots or curves of this sort are seen in the first two charts shown on Fig. 4.

Factory inspection tests can be reduced to a comparatively simple routine after the first few instruments of each pattern have been inspected. The purpose of such tests is to control the quality of the output.

The short test for service instruments is an attempt to secure, in a minimum time, such data regarding the maximum calibration correction or temperature effect as may be needed for actual reference in connection with the installation or use of instruments on aircraft.

The Bureau of Standards general test is the one which is furnished on instruments submitted to the Bureau without special instructions. It is a comprehensive standard form of test affording a complete calibration curve together with, at least, numerical values for the more common errors due to temperature and other well-known conditions.

The Bureau makes more thorough tests on sample instruments of new type whose mechanism is not familiar. Such additional observations usually include some form of accelerated life test, such as a five-day run to determine the endurance of the instrument under vibration. The steadiness of the pointer and the accuracy of the instrument with and without vibration are observed in such a test.

The special tests on experimental instruments depend of course on the nature of the work for which the instrument is to be used, and on the flight conditions which will prevail. For instruments such as aneroid barometers, which involve serious errors due to elastic lag or temperature lag, there can be no more reliable method of determining the corrections necessary for the interpretation of the readings than to make a flight-history test by actually reproducing in the laboratory the identical variation of pressure, temperature, etc., which was experienced from time to time during the flight. This is particularly important in connection with the use of barographs for competitive altitude flights. It is now well known that barographs subject to any appreciable amount of elastic lag will read a higher altitude the greater the time elapsed during the flight.

It is a short step from some of these more complete testing methods to the general subject of the experimental investigation of sources of error in instruments. Such investigations have

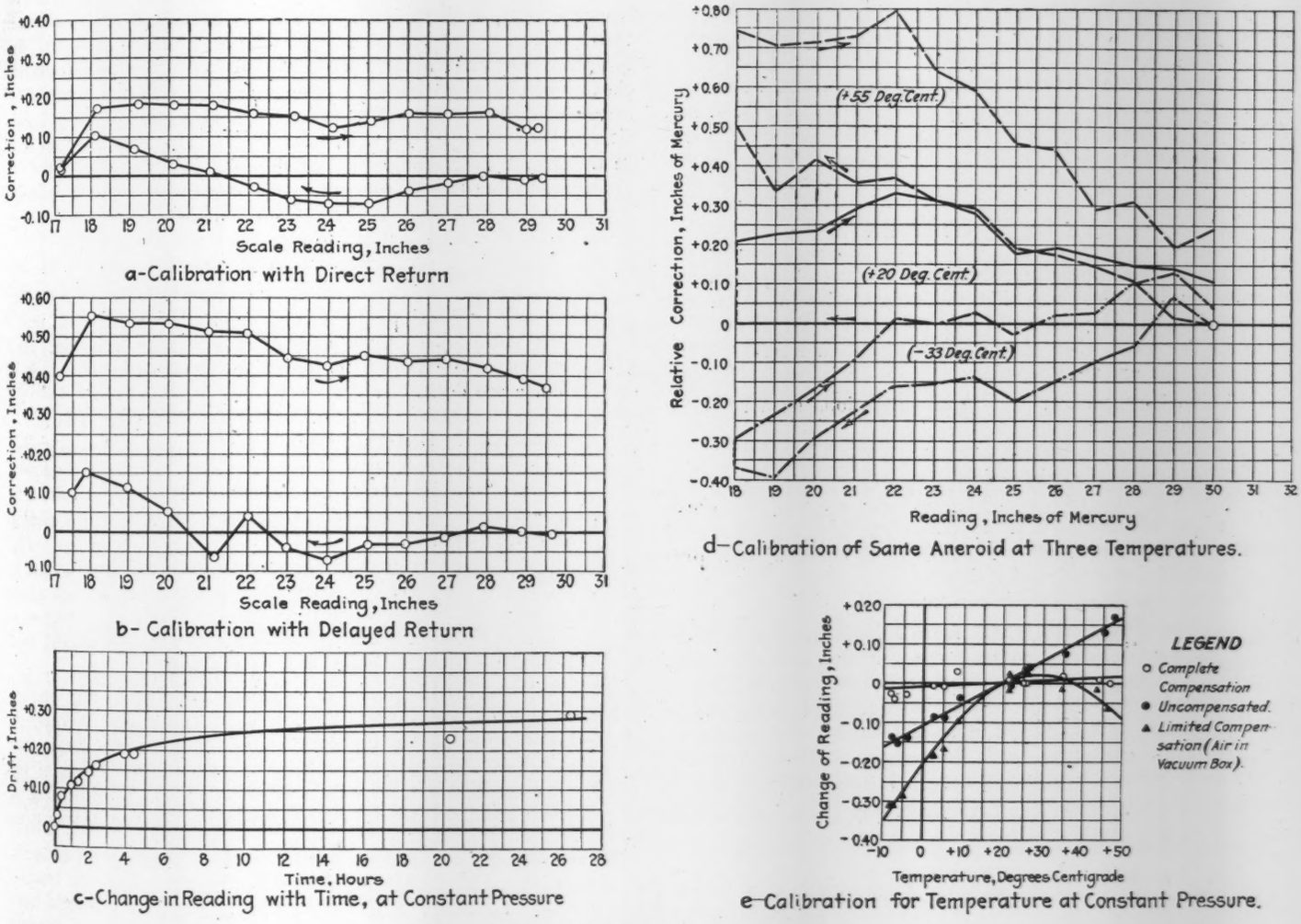


FIG. 4 TYPICAL INVESTIGATION RESULTS

formed one of the most interesting features of the work of the Bureau of Standards and are illustrated by the examples given in Fig 4.

In this figure five charts are shown based on experiments with high-grade commercial aneroids. The first chart (*a*) shows the ordinary calibration of an aneroid changing the pressure at the rate of an inch of mercury in five minutes. (At sea level one inch of mercury corresponds to about one thousand feet of altitude. At twenty thousand feet one inch corresponds to about two thousand feet of altitude). The calibration curve would be distinctly different at some different speed, due to elastic lag in the corrugated-metal vacuum boxes. For the same reason, as shown in chart *b*, the discrepancy between the readings going up and coming down is much greater when the aneroid is held at the maximum altitude for a considerable time interval. This drift, or change of reading at constant pressure, is shown in chart *c* as a

function of the time elapsed. These curves may be taken as a criterion of the elastic quality of the material in the instrument; and several hundred such have been determined in the course of the Bureau's investigations. Chart *d* shows the increase in the width of the hysteresis loops with rise of temperature, and it also shows the decrease in the sensitivity of the movement when an instrument is chilled. This last effect is largely due to the change of elasticity with temperature, and cannot be fully compensated for by means of the ordinary bimetallic lever. The remaining chart (*e*) shows what can be done in the way of temperature compensation. Of three superimposed curves one represents a typical uncompensated aneroid. The graphs show the change of reading with temperature at a constant pressure corresponding to sea-level conditions. A second curve shows a partial degree of compensation obtained by admitting air to the vacuum box. The remaining curve shows satisfactory compensation by means of a bimetallic bar for sea-level observations; but this same aneroid may have a serious temperature error when the movement has shifted into the new position which it will occupy at twenty thousand feet.

Still further characteristics of aneroid barometers have been studied at the Bureau in addition to those shown in Fig. 4, and similar investigations have been extended to all of the other aeronautic instruments.

## 3 USE OF INSTRUMENTS

Many practical airplane pilots disclaim the use of instruments, and certainly it is desirable that the aviator should be trained to become just as independent of any mechanical aid as possible.

Some of the times when airplane instruments are really of the most importance are the following:

*a* For various military and naval operations such as bomb dropping
*b* Long-distance navigation
*c* Flying at night and in clouds
*d* Preparing to land on a perfectly smooth body of water where the height is deceptive
*e* Flying in formation with instructions to hold to a prescribed air speed and altitude
*f* Photographic and survey work.

The need for instruments is still more evident in airship work. Here it is necessary to control the position of the ship, especially near the ground, with comparatively greater precision; nor is it possible for the pilot to act so quickly in response to his unaided senses as it might be in an airplane.

The following precautions may be suggested for getting the best results in the practical use of service instruments:

*a* Select for installation in the first place only those instruments which can be certified by the Bureau of Standards as suitable for the intended use.
*b* In any event see that the instrument is tested immediately prior to installation to avoid the occurrence of large errors due to secular changes or mechanical injury.
*c* When accuracy is required in flight observations the aviator must remember where appreciable lag errors are stated to exist, whether due to elastic lag or temperature lag or other causes, that some time will be required for the instrument to completely respond to any given change, and that the results will be different with increasing and decreasing scale readings.
*d* At least once in six months it is desirable that instruments should be overhauled, during which time they may perhaps be replaced by a reserve supply of fresh instruments properly tested and adjusted.

The problem of salvaging has been studied by the Bureau of Standards and the statistical results of such work are of the greatest value as a basis for future improvements in instrument construction. The actual salvage proposition consists of dismantling a certain number of damaged instruments and putting them together again so as to form a smaller number of good instruments. The study of expedients for readjusting the mechanism forms an integral part of such work. This can only be done in the testing laboratory.

In concluding this paper, a recapitulation may well be made of some of the outstanding problems of instrument development, the solution of which is much to be desired:

*a* A satisfactory gasoline depth gage is needed.
*b* Barographs and other recording instruments of better quality than any now existing are needed. Better clockwork, and a much more open scale, and more complete freedom from errors due to friction, temperature, elastic lag, and lack of balance are desirable.
*c* A wholly satisfactory form of compass for airplanes is not as yet available. Besides the northerly turning error, so-called, to which all single-pivot compasses are necessarily subject, there are troubles due to the action of the damping fluid.
*d* Air-speed indicators suitable for the low speeds of airship flight are required.
*e* A gyro-stabilizer is needed, different from existing types in that it must be able to stabilize a body which is not rigid, but contains a freely moving mass. Such a stabilizer is necessary before the full possibilities of any dynamical type of ground-speed indicator can be realized.

The material in this paper is of course not due to any one individual, but is based upon the work of the entire Aeronautic Instruments Section of the Bureau of Standards. Later, the detailed official reports prepared by the various members of the staff concerned, should be available through the publications of the Bureau and the National Advisory Committee for Aeronautics.

# The Rectilinear Flight of Aeroplanes

## Basic Principles of Analytical Theory Advanced by Eminent French Engineer and Scientist and Their Application—Calculation of Maximum Cruising Radius

By A. RATEAU,[1] PARIS, FRANCE

IN his paper, of which the following is an abstract, M. Rateau presents the basic principles underlying his theory of the rectilinear flight of aeroplanes, and further indicates how they may be applied in the solution of certain important aeronautical problems. In doing this he establishes at the outset characteristic relations connecting the main factors governing the operation of the propeller.

The paper is based on the assumption that a constant-compression, not supercharged, engine is used, the carbureter being equipped with an altitude regulator, in order to maintain the mixture at the optimum ratio all the time, and that further the propeller is of constant pitch, is not subject to deformation, and is held on the motor shaft.

The same theory may apply to a propeller with gear reduction, but the author does not wish to introduce into his equations the complications created by the use of gear reduction between the motor and propeller.

One of the most essential elements affecting flight is the specific weight of air at the different altitudes, and the author establishes a formula connecting the specific weights of air at the ground and at various elevations.

As regards the engine, the most important factor is not the

[1] Mem. Institut de France; Hon.Mem.Am.Soc.M.E.

Abstract of paper to be presented at the Spring Meeting, St. Louis, May 24 to 27, 1920, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Advance copies of the complete paper may be obtained gratis on application. All papers are subject to revision.

power output, which varies with the speed, but the couple which it sets up, and if the carbureter is properly adjusted this couple should vary but little with the speed of rotation in revolutions. It is, however, tremendously affected by the specific weight of the air sucked in, though not proportional to it.

On the other hand, the consumption of fuel and oil in an engine varies with the speed of rotation and with the specific weight of air. As regards fuel consumption, if the carbureter is properly adjusted it varies in proportion to the total weight of the air sucked in, and hence in proportion to the speed of the engine and to the specific weight of air. The oil consumption depends on the character of the oil and the temperature of the air with which the engine is supplied, and increases with the speed of the engine more rapidly than the speed itself.

The consumption of both fuel and of oil is affected by a number of factors in such a manner that it is impossible to keep track of them in an exact manner. It may be said to be proportional to $\omega + o$ where $\omega$ is the specific weight of air and $o$ is a constant, the numerical value of which is about 0.08 in the case of non-rotary motors lubricated by castor oil and a little larger, say, about 0.1, in the case of mineral oil, and still larger for rotary engines.

Considerable attention is devoted to the characteristic functions of the propeller. In this connection only the effective pitch of the propeller and not the so-called "nominal pitch" is taken into consideration. While the effective pitch is of a physical character and therefore cannot be measured directly on the propeller, it is nevertheless of the nature of a constant characteristic of the propeller, no matter what the speed of the latter may be.

The following basic formulæ are established by the writer:

Theory shows that the tractive force $F$ of the propeller in kilograms and its counteracting couple $\Gamma$ in kilogram-meters are expressed by the relations

$$\left.\begin{aligned} F &= b\omega n^2 f(\sigma) \\ \Gamma &= \frac{bH}{2\pi}\omega n^2 \varphi(\sigma) \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots [1]$$

where $f(\sigma)$ and $\varphi(\sigma)$ are the functions of slip and of certain coefficients of the propeller mentioned later, and where $b$, which the author calls the factor of thrust, has for its expression in the case of aeroplane propellers with narrow blades—

$$b = \frac{2k\pi}{g} HM \ldots\ldots\ldots\ldots\ldots\ldots [2]$$

where $\pi$ is the ratio of circumference to diameter; $g$ the gravitational constant in metric units ( $= 9.81$); $k$ a numerical coefficient of the order of 2, and $M$ the moment, referred to center of propeller, of the projection of the active surface of the wings on a plane perpendicular to the axis. The units in the case of $H$ and $M$ are the meter and the square meter.

The function $f(\sigma)$ is of the form $\sigma(1 - e'\sigma)$ where $e'$ is the coefficient depending on the ratio $p$ of the pitch $H$ to the peripheral diameter $D$ of the propeller and decreases in a certain proportion to the decrease of the ratio above referred to. When $p$ is less than unity (and this is the case with practically all aircraft propellers), $e'$ is less than 0.01. Since, on the other hand, the slips $\sigma$ as a rule vary only from 0.2 to 0.4, it can be seen why the corrective term $e'\sigma$ varies only by about 0.016 in particular applications and hence may be entirely neglected when subtracted from unity. This is what the author does. At the same time, whenever necessary, the complete formula makes it possible to carry out the calculations with the necessary degree of precision.

The function $\varphi(\sigma)$, which is of basic importance, has the form

$$\varphi(\sigma) = a + \sigma - e\sigma^2 \ldots\ldots\ldots\ldots\ldots\ldots [3]$$

where $e$ always has a value in the neighborhood of 0.5 and $a$ of 0.03, and are variable from one propeller to another in accordance with its shape and roughness of the surface. It is only this $a$ that is affected by losses in the propeller due to shocks, friction and turbulence of the fluid; it is connected with the coefficient $\varepsilon$ (loss of relative velocities across the propeller) by the formula—

$$a = \varepsilon\left(\frac{p}{\pi\nu} + \frac{\pi\nu}{p}\right)^2 \ldots\ldots\ldots\ldots\ldots\ldots [4]$$

where $\nu$ is the ratio of a certain average radius to the radius of the periphery.

If it be assumed that $e = 0.5$, then

$$\varphi(\sigma) = a + \sigma - \frac{\sigma^2}{2} \ldots\ldots\ldots\ldots\ldots\ldots [5]$$

and hence

$$\psi = \frac{\varphi(\sigma)}{f(\sigma)} = 1 - \frac{\sigma}{2} + \frac{a}{\sigma} \ldots\ldots\ldots\ldots\ldots\ldots [6]$$

This function $\psi$ of the slip is one that constantly occurs in the author's aeroplane formulæ.

The efficiency of the propeller $\rho$, if by $v$ is denoted the velocity of advance, is

$$\rho = \frac{Fv}{2\pi n \cdot \Gamma} \ldots\ldots\ldots\ldots\ldots\ldots [7]$$

If $v$ is replaced by $nH(1 - \sigma)$, and $F$ and $\Gamma$ by their expressions taken from Equation [1], then

$$\rho = \frac{f(\sigma)(1 - \sigma)}{\varphi(\sigma)} = \frac{1 - \sigma}{\psi} \ldots\ldots\ldots\ldots\ldots\ldots [8]$$

Attention is called to the fact that in this expression of the efficiency of the propeller, in which $\psi$ may be used in the form given by Equation [6], only the slip $\sigma$ and the coefficient of losses $a$ are used.

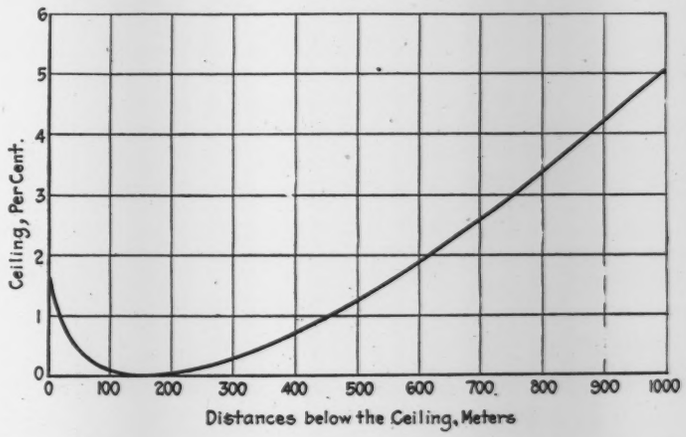


FIG. 1 VARIATION OF FUEL AND OIL CONSUMPTION PER KILOMETER OF FLIGHT WITH VARIATION IN DISTANCE OF PLANE FROM ITS CEILING DURING FLIGHT. (COMPUTED FOR AEROPLANE-TYPE)

All these novel and fundamental formulæ are excellently confirmed by experiments as precise as one could wish for in a subject of such complexity as the one under consideration.

## CHARACTERISTIC FUNCTIONS AND COEFFICIENTS OF AN AEROPLANE

For a given aeroplane the essential variables are its weight $P$ in kilograms and its incidence $\alpha$, that is, the angle in degrees formed by the wings with the trajectory.

Formulæ are established connecting in horizontal rectilinear flight the weight of the aeroplane $P$ and the resistance $R$ to forward motion, where both $P$ and $R$ are expressed in terms of specific weight of air $\omega$ and velocity of movement of the plane $v$ in the form of

$$P = Y\omega v^2 \ldots\ldots\ldots\ldots\ldots\ldots [9]$$

and

$$R = X\omega v^2 \ldots\ldots\ldots\ldots\ldots\ldots [10]$$

where the coefficients $Y$ and $X$ for each given plane are functions of the incidence $\alpha$. As such they are expressed in the form of

$$\left.\begin{aligned} Y &= Y_o(1 + \eta\alpha) \\ X &= X_o(1 + \xi\alpha^2) \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots [11]$$

where $Y_o$, $X_o$, $\eta$ and $\xi$ are the four specific coefficients of an aeroplane which have to be determined by measurement or computation.

As an example, the author considers a supposititious airplane

(Continued on page 316)

# River Transportation in the Mississippi Valley

## Recent Progress in Construction and Operation of Barges and Towboats—Need for Waterways Transportation—Developments Under the Federal Control Act

By E. W. SCHADEK,[1] ST. LOUIS, MO.

*A review of recent progress in the construction of barges and towboats for river transportation, particularly in the Mississippi River Section, and of provision made for their operation. The towboats are of the screw-tunnel type with new features. Traffic by rail in the Mississippi Valley has long since reached the capacity of the railroads. The need for water transportation facilities was recognized by the Government during the war, and under the Federal Control Act appropriations were made for the construction and operation of river fleets. When the vessels are completed and placed in service, a good start will have been made in utilizing our national waterways for the development of industries and commerce.*

THAT great part of our country lying between the Allegheny and Rocky Mountains, known as the "Mississippi Basin," contains more than one-half of the country's population and produces three-fourths of its food products and one-half of its manufactured products. The Mississippi Valley district includes 21 states and has an approximate area of 1,725,000 square miles, with 120 cities having a population of more than 25,000 each. It furthermore contains a number of great ports and in addition the country's greatest waterway.

The capacity of the railroads of the Mississippi Valley has long since been reached. Every one knows of the annual shortage of cars during the crop-moving season, but few realize how greatly this interferes with the flow of commodities from farmer to consumer. To provide ample rolling stock, trackage and terminals to take care of this peak load, however, would impose on the railroads too great an investment in equipment for a comparatively short period of the year, so that the only remedy for the situation is the improvement of waterways as recommended many times by the engineers studying this situation. It has been computed that the capital saving in rolling stock of the extra equipment alone would pay for the entire cost of the waterway improvement within a comparatively few years.

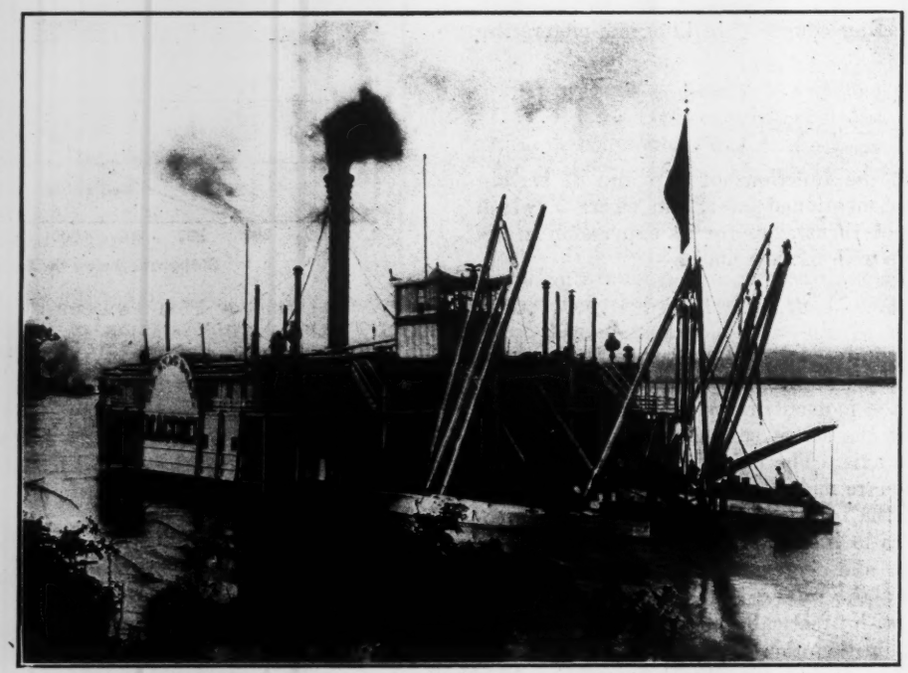

FIG. 1 U. S. SNAGBOAT *J. N. Macomb*. STEEL HULL BUILT IN 1874
Showing snag drawn up between catamaran bows, to be sawed up and destroyed.

Our government has spent many millions of dollars upon the river improvements in the last 40 years, but hardly one-half of the necessary work has been accomplished up to the present time.

The Newton Bill, pending in Congress, calls for completion of the improvements, and covers:

9-ft. channel in Ohio River from Pittsburgh to Cairo
9-ft. channel in Mississippi from Cairo to New Orleans
8-ft. channel in Mississippi from Cairo to St. Louis
6-ft. channel in Mississippi from St. Louis to St. Paul
6-ft. channel in Missouri River from Kansas City to Mississippi River

### PROVISION MADE DURING THE WAR FOR NEW FLEETS AND THEIR OPERATION

During the World War the Government recognized the importance of adequate waterways in time of need. The Federal Control Act appropriated funds for new fleets and for immediate operation upon inland waterways in which were comprised the following developments:

An appropriation for the Mississippi-Warrior section provided for the construction of a new fleet on the lower Mississippi River, to consist of six tunnel towboats, 200 ft. by 40 ft. by 10 ft. in dimensions, and 40 new steel barges each 230 ft. by 45 ft. by 11 ft. The larger number of these barges is completed and the balance, according to reports, will be ready before June 1. Deliveries of the six new steel towboats were scheduled for March, June, and July, so that the complete fleet is expected to be in operation by the end of July.

The barges under construction for the lower Mississippi River have a capacity 2000 tons each, on 8 ft. draft, which is twice the capacity of the largest barges operated in the present fleet. One barge has a capacity equal to 100 cars. The towboats for this new fleet are of 1800 hp. each, with a capacity to tow downstream five of these barges, making a total of 10,000 tons, or 500 carloads.

An appropriation of about $5,000,000 provides for the construction of a new fleet on the Warrior, Alabama and Tombigbee Rivers, to consist of four steel, self-propelled barges of the double-tunnel type and three tunnel towboats, each 140 ft. by 24 ft. by 6 ft. As the bulk of the tonnage on these rivers consists of coal from Alabama fields to New Orleans and Mobile, 20 steel cargo retainers of 10 tons capacity each were constructed to stimulate other cargo for northbound trips, and derricks are being installed at terminals to facilitate handling.

In the very near future there will not be a city or town on the Warrior and Tombigbee River without port facilities. Plans are being drawn and estimates made of the cost of terminal facilities at Demopolis and Jackson, and also at Spocari, six miles from Demopolis. Two turning basins are to be established on the Warrior River, one directly opposite the port of Birmingham and the other at Locust Fork. These basins, dredging work for which

[1] The Ruemmeli-Dawley Mfg. Co. Mem. Am. Soc. M.-E.

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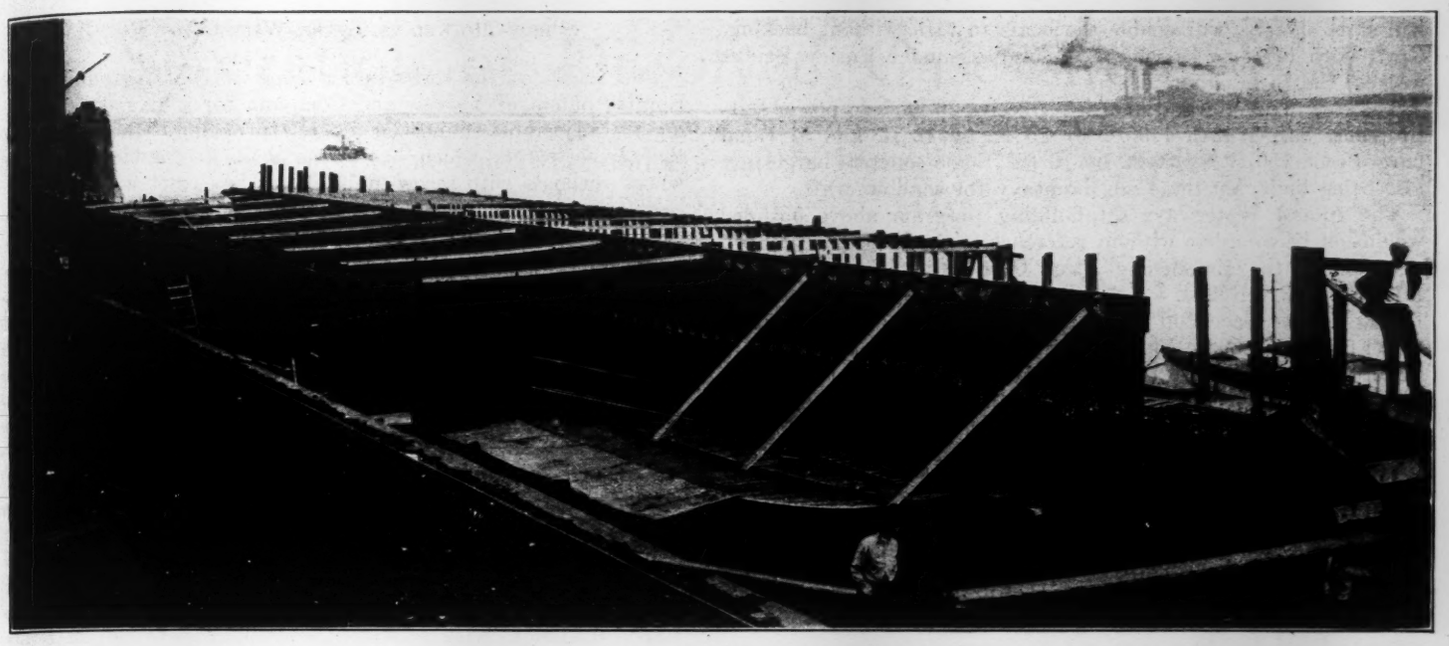

FIG. 2 ASSEMBLY OF FLOORS, CENTER-LINE BULKHEADS AND SIDE FRAMES ON ONE OF THE BOATS AT THE EARLY STAGE OF CONSTRUCTION

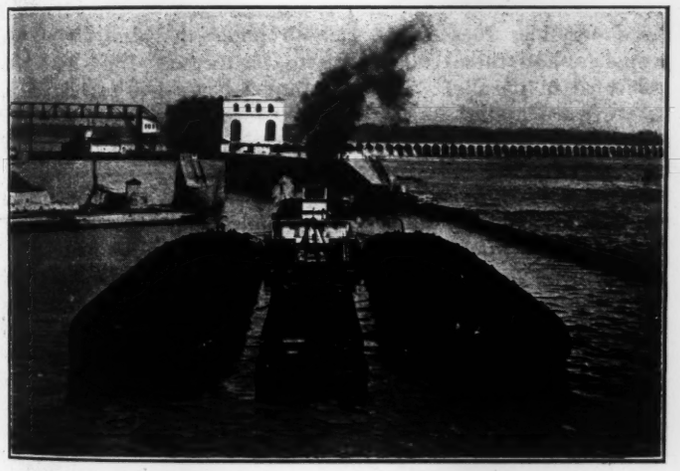

FIG. 3 TWO 3000-TON UPPER MISSISSIPPI RIVER STEEL BARGES IN TOW OF U. S. DREDGE *H. S. Taber*, BELOW DAM, KEOKUK

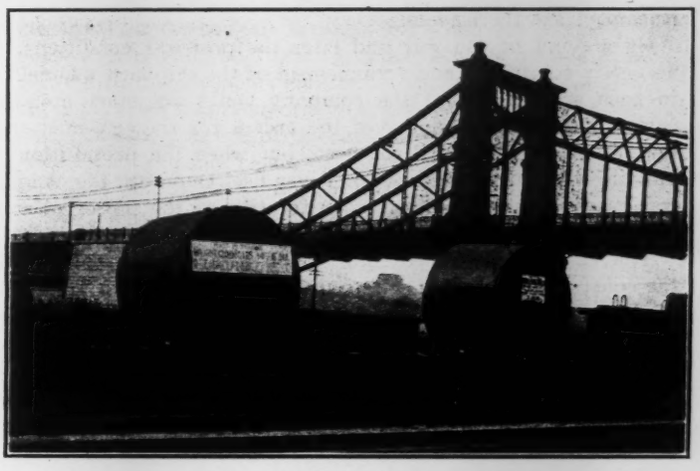

FIG. 4 SCOTCH MARINE BOILERS BUILT IN ST. LOUIS, HERE SHOWN BARELY CLEARING THE GRAND AVENUE VIADUCT

FIG. 5 SHOWING THE BOAT FAIRLY ADVANCED WITH THE FORWARD-CARGO, CENTER-CARGO AND BACK-CARGO SPACE, PRACTICALLY COMPLETED AND WITH THE ENGINE-ROOM AND BOILER-ROOM SIDES UP

will start shortly, will enable the boats to turn without backing. Craft with high stacks which cannot pass under Ensley Bridge will use the Birmingham basin.

The New York Barge Canal is to receive 20 modern power self-propelled barges each 149 ft. by 20 ft. by 12 ft. and 51 canal barges each 150 ft. by 20 ft. by 12 ft. Some concrete barges are also being built, but these are too heavy for shallow draft.

The Inland Waterways shipbuilding program above outlined would not be complete without reference to the $3,860,000 appropriation of the Emergency Fleet Corporation for the Upper Mississippi River fleet, which will consist of 19 of the most up-to-date barges, each 300 ft. by 49 ft. by 10 ft., and four stern-wheel towboats 230 ft. by 58 ft. by 8 ft. This fleet is being built under the direction of the U. S. War Department, Engineers Office, St. Louis District, headed by Major Wilbur Willing, and Mr. Wm. S. Mitchell, Assistant Engineer, who are directing the designing and construction.

### Participation in Boatbuilding by St. Louis

When the Government program of building river fleets became known to some of the leading citizens of St. Louis they decided that this city should also be represented in the shipbuilding program. A shipbuilding company was accordingly organized and incorporated under the name of St. Louis Boat and Engineering Company, of which Mr. Edward A. Faust and Mr. Albert Ruemmeli are the leaders.

On account of the war and later the post-war conditions, the necessary equipment and arrangement of the shipyard was delayed to such an extent that the company could not start operation early enough to secure any of the orders for the construction of the Lower Mississippi River fleet; but when the proposition for building the Upper Mississippi River fleet came up, the company was ready and received an order for two of the powerful stern-wheel towboats.

The U. S. Railroad Administration awarded the contract for the construction of four self-propelled barges for the Tombigbee, Alabama and Warrior Rivers to the St. Louis Boat and Engineering Company, and these boats are now being built in the first St. Louis construction shipyard. They are of the twin-screw steel tunnel type, 280 ft. long, 49 ft. wide and 10 ft. deep, and are built for a maximum draft of 7 ft. They are of single-deck, shallow-draft, flat-bottom type, built entirely of steel. The machinery enclosure is located aft, and the cargo space is all on deck, consisting of two steel houses for package freight, one forward and one aft, and two steel guards amidship forming coal-cargo space. The forecastle head is raised to accommodate part of the crew, and other crew quarters are located above the machinery enclosure. The pilot house is raised and the captain's room is located above. The center-line bulkhead extends from keel to deck and from forward collision bulkhead to engine-room bulkhead, all watertight. The cross bulkheads in these barges are six in number.

The propelling machinery consists of two 400-hp. vertical, triple-expansion condensing engines, and of two marine-type water-tube boilers for 250 lb. working pressure, arranged for forced draft, for which a fan of 10,000 cu. ft. of air is provided. All auxiliaries are arranged for running condensing to collect the condensate for feedwater, and the make-up water is carried along in tanks, two of which are forward underneath the crew quarters and the other four are next the engine room. The total capacity of these six tanks is 135 tons of water. The surface condenser has $^3/_4$-in. outside diameter tubes with 1100 sq. ft. of condensing surface. The propellers are four-bladed, two in number, each 6 ft. 4 in. in diameter, 6 ft. 9 in. pitch.

The most interesting feature of the construction of these self-propelled barges is the selection of propeller drive instead of the paddle-wheel drive which, up to the present time, has been in use on our rivers. It is known that the propeller drive is 25 per cent more efficient than paddle-wheel drive, permitting more compact arrangement of machinery and reducing not only the size and initial cost of the boat, but also its operating expense.

### Screw-Tunnel vs. Stern-Wheel Towboats

The origin of the screw-tunnel type of boat is found in the English patent of Yarrow and Company for a hinged flap forming the adjustable tunnel for a screw propeller. In this country the few attempts which have been made to replace the stern-wheel towboats with screw-tunnel boats have met with little success because the latter type of boat has not been found effective for towing purposes. While making curves with tow, towboats must flank or reverse the rotation of the wheel or propeller, in order to throw water against the rudders so as to turn the tow, which precedes the boat, and prevent its grounding on the bank of the river. The rudders of a stern-wheel towboat are connected in parallel and at flanking the boat will throw against the rudders all the water the wheel is capable of handling, making a powerful flanking.

The present tunnel towboats, besides having the ability to steer and flank, are also able to twist (where one engine runs forward and one astern). Their flanking ability with both engines running astern, however, is less than one-half that of stern-wheel towboats, and twisting, combined with flanking, reduces the total ability to handle the tow to about one-third that of stern-wheel boats. All this is well known to river "rats," hence their skepticism about tunnel towboats.

The new-type tunnel boats now being built will overcome the defects of the present-type tunnel boats by introducing independent control of starboard- and port-side rudders. A tunnel towboat has one rudder forward of each propeller and one aft of each propeller, and these rudders up to the present time have been connected in parallel. The new tunnel boats will have rudders, one forward and the other aft of propeller on port side, controlled by one steering mechanism; and in the same way rudders on the starboard side will be controlled by another steering mechanism. All is ingeniously constructed so that the rudders can be operated in parallel or independently, either by power or by hand, from pilot house or forecastle.

By independent control of the two sets of rudders, the total ability to handle a tow combines that which comes from steering, twisting, flanking and side thrust of propellers, so that, when steering is not sufficient for handling the tow, the ability of flanking is increased by the ability to twist and side thrust, making the total ability to handle the tow as great as for the stern-wheel towboat, when this ability is based on the proportions of available horsepower propelling the boats.

The ingenious design of this rudder control was introduced and designed by the well-known firm of naval architects, Cox and Stevens, of New York. They have been engaged by the U. S. Railroad Administration to design and direct the construction of the new fleets as previously outlined.

### Importance of Waterways Transportation

When all the vessels comprising the U. S. Railroad Administration program are placed in service, a fairly good start will have been made in utilizing our national waterways for the development of the industries and commerce of the Mississippi Valley. The importance of the waterway transportation to the development and welfare of any state or city is clearly shown in the project for which the state of Illinois appropriated $20,000,000. The project is to connect the terminus of Chicago drainage canal in the Desplaines River at Lockport with the Illinois River at Utica, a distance of about 60 miles. When this is completed the route from Chicago to the Gulf will be realized. Time for construction of the new canal is estimated as 5 years and the carrying capacity of this new waterway 60,000,000 tons a year. The capacity of the Government's new fleet for the Lower Missippi River between St. Louis and New Orleans is 1,000,000 tons. This gives us an idea what is still to be accomplished in building new fleets to fully utilize the waterways transportation.

There are now 600 firms in St. Louis selling in foreign markets and they did about $75,000,000 worth of foreign trade business in 1918, increasing this about 25 per cent during the year 1919.

# The Separation of Dissolved Gases from Water

## Description of a Method Therefor, Together with Particulars Regarding Its Use in Inhibiting Corrosion in Boilers and Economizers and in Increasing the Conductivity of Surface Condensers

By J. R. McDERMET,[1] PITTSBURGH, PA.

*This paper covers the results of a research on the separation of dissolved gases from water, both on a laboratory and a commercial-plant scale. Fundamentally the process consists of the rapid injection of heated water into a region of vacuo, and an explosive boiling of it at the expense of the heat of the liquid available to the vacuum, with a simultaneous recovery of the heat liberated to the vacuum by a heat exchanger or condenser cooled by the incoming water, preliminary to its heating. It is possible to deduce from a résumé of existing knowledge the results to be expected in the elimination of corrosion from boilers and economizers fed with oxygen-free water. Test data are submitted to show the economies to be gained from the surface condensation of steam free from non-condensable gases both in increased conductivities and higher vacua, and chemical analyses suggest the elimination of carbonates dissolved in water as bicarbonates in excess of their true solubility as carbonates.*

THE idea upon which the method of separating dissolved gases from water described in the present paper is based was originated by Mr. W. S. Elliott of Pittsburgh and sponsored by him for development under the industrial fellowship system of the Mellon Institute of Industrial Research, Pittsburgh, Pa. It appeared at the conclusion of the laboratory investigation that the process evolved from the idea successfully fulfilled three requirements which were regarded as necessary for commercial utility: It was able to handle water in quantities sufficient for the feeding of power-plant boilers with a minimal operating expense and was particularly applicable to this service; it was capable of removing all of the dissolved gases in a commercial sense; and it involved no methods or apparatus with which the average operating engineer was not familiar. The scale of experimentation was therefore enlarged, but the basic idea underwent no change.

The solution of gases in water obeys Henry's law, which states that a solvent in contact with a gaseous mixture dissolves the component gases in proportion to the partial pressures which they exert, provided they do not unite chemically with the solvent. Carbon dioxide which unites chemically with water deviates from this law, but is itself of variable content in atmospheric air. With this reservation in mind, it is possible to say that if extraction is complete, the gas mixture extracted from water is precisely of the same composition as air from which solution was attained. At incomplete extractions proportionality factors between the components appear due to different degrees of solubility. The process with which this paper deals might therefore with perfect propriety be called "air separation."

The initial laboratory installation consisted of an instantaneous water heater drawing its water under pressure from a supply main, and delivering heated water under thermostatic control to the spray head of a separator. The separator consisted of an airtight steel tank with a series of copper return-cascade pans supported by a central steel column, over which the spray head delivered water uniformly in a thin sheet. The separator tank was connected with a barometric tail-pipe column at the bottom to remove the treated water and with an air-pump connection at the top. Vapors and gases were withdrawn from the air-pump connection through a small condenser cooled by the supply water to the heater, and equipped with a trap for retaining condensate. Non-condensable gases were withdrawn from the condenser by a variable-speed motor-driven air pump and passed to a displacement air bell, adapted from a standard gas-meter prover, for collection and measurement. Thermometer wells were installed to indicate all significant temperatures and weighing tanks to collect and measure treated water. The condensate trap was so valved that it could be cut in and out of the system for the purpose of collecting the condensate over stated periods, and the air bell collected all non-condensable gases. While the provisions for determining all data but volume of non-condensable gases proved adequate and satisfactory, it was immediately discovered that the air-bell data were not of consistent accuracy in spite of the laboratory tightness of the complete system. It was accordingly necessary to turn to direct testing of the water which had passed through the process. The laboratory arrangement is indicated in the diagram of Fig. 1.

Three methods, developed previously by experimenters in other fields, were utilized in testing for the dissolved gas content, after careful checking had established their accuracy; (*a*) The iodiometric titration method of Winkler for dissolved oxygen; (*b*) Freeman and Preusse's modification of Reichardt's method of boiling; and (*c*) a displacement with either carbon dioxide or hydrogen. As experience soon demonstrated, the degree of separation of dissolved gases was so complete that the proportions of constituent gases were the same as for atmospheric air. When this fact was definitely confirmed by a long series of pipette analyses, reliance was placed entirely upon the chemical titration method of Winkler.

At the conclusion of about four months' intermittent testing the apparatus was taken apart and examined. Steel tank, copper pans and condenser gave evidence of very accelerated corrosion. Cognizance of this virulent action was taken in the design of the first commercial apparatus, and the separator was made entirely of cast iron and non-corroding bronzes, which materials have withstood the corrosive tendencies for over four years of experimental operation.

The laboratory experiments also developed a further fact which was the cause of much confusion at the outset. Water which has been passed through this process and completely degasified is never in equilibrium with the temperature as far as solubility is concerned. Such water has an enormous avidity for redissolving small amounts of air and it is only by the most painstaking manipulation that accurate results are possible in the determination of the extent of separation. In the practical application of the process, absolutely rigid exclusion of air must be maintained if the full benefits of the process are to be secured.

Empirical design factors governing separator volumes, pan areas, and the proportioning of the injection nozzle were adopted from the laboratory installation and embodied in the first commercial installation which was put in service in the Jeannette, Pa., works of the Elliott Company of Pittsburgh in the autumn of 1915. This installation has been in routine operation since that time. The separator proper was designed for 1000 boiler hp. at the outset, and consisted of a 100-hp. Elliott cylindrical heater shell with modified water injection, different proportions of water-storage volume and pan area, and a change of materials to resist corrosion. This design of separator has been retained intact, but the auxiliary arrangement has been modified three times. At the outset a 300-hp. open feedwater heater was installed to supply hot water, and vacuum was maintained by a rotary motor-driven dry-air pump in series with a condenser. Condensate from the condenser was allowed to drain back into the separator, and the air pump discharged non-condensable gases directly into the atmosphere; otherwise the scheme of connections was identical with that in Fig. 1.

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An increase in boiler capacity later made necessary the installation of a 1000-hp. heater of the same shell type as the separator, and the entire outfit was repiped and made into an integral vertical unit as shown in Fig. 2. Simultaneously the mechanical air pump was replaced by a steam ejector and the condenser was mounted on the atmospheric side to recover the ejector steam, condensate drainage being now into the heater instead of the separator.

It was felt at the beginning that condenser conductivities would be very low on such vapor mixtures as are withdrawn from the separator of an air-extraction apparatus, and a condenser of a relatively large capacity was installed. This condenser was removed from the apparatus when opportunity permitted and tested under the same circulation rates and with steam-air mixtures of the same composition as those imposed in practice. These tests gave a condenser conductivity of from 50 to 60 B.t.u. per hr. per sq. ft. per deg. fahr. temperature difference. The condenser operates, however, with a large temperature gradient, and the actual transfer per unit of surface is very high. The design is strictly conventional, having four water passes with the circulation through the tubes.

Fig. 3 is plotted between percentages of separation as ordinates and vacua referred to a 30-in. barometer as abscissæ for a water-temperature admission to the separator of 212 deg. fahr., corresponding to atmospheric equilibrium. This curve is the graphical average of a large number of determinations made both with the laboratory and the commercial-size apparatus. Percentage of separation is defined for the purposes of these curves as the ratio of the quantity of gases removed to that actually present in the raw water, and the calculations were made in terms of volume. Calculation in terms of weight would, however, have had identical values.

The mechanism of the separation appears to depend upon three factors: namely, the natural decrease of solubility with temperature, the mechanical agitation of boiling, and the reduction of pressure. The reduction of solubility with heating amounts roughly to 70 per cent of the volume at normal temperatures, and separation to this extent was arbitrarily credited to the heater.

Water at 212 deg. fahr. injected suddenly into the region of vacuum of the separator has considerable heat available to the vacuum and boils with explosive violence at the expense of the heat of the liquid, behaving exactly as though it were superheated. Vapor bubbles form upon minute entrained air bubbles as nuclei, and in passing off into the region of reduced pressure mechanically take some portion of the dissolved air with them.

By far the major portion of the separation, particularly in the elimination of the final traces of dissolved gases, is accomplished by the reduction of partial pressure and represents a simple application of Henry's law. The water flows through the separator in thin sheets exposed to a vapor mixture corresponding in pressure to the vacuum maintained. Under steady conditions of operation at a pressure reduction in the separator of 10 in. of mercury and admission temperature of 212 deg. fahr., this vapor mixture corresponds to an air content roughly 0.11 per cent by weight but 0.07 per cent by volume. The water vapor is undoubtedly in equilibrium with its liquid, and as such is relatively dense and moist. With a separator water-storage volume corresponding to two minutes' operation at rating, it is impossible to detect at any rate of operation a temperature depression in the vapor mixture or in the water leaving the separator below that corresponding to the vapor temperature of the vacuum. Water, vapor, and total pressure are therefore in equilibrium. The most

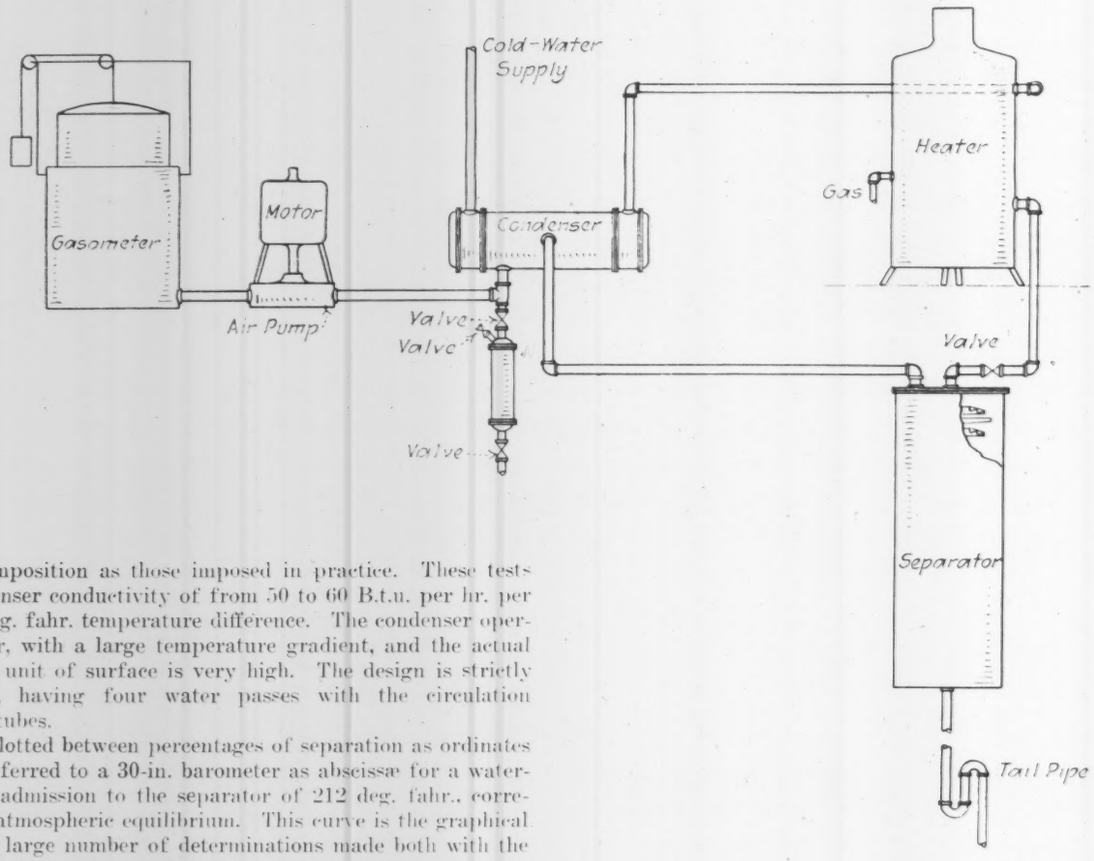


FIG. 1 LABORATORY SEPARATION EQUIPMENT

logical conclusion to be deduced from this is that, with the continuous sweep of the wet, dense water vapor from the separator, the air component of the vapor pressure has been reduced by entrainment substantially to zero, and that the process has furnished a very simple and efficient means of securing such a reduction of pressure. Experiments by the writer have confirmed the results of other investigators that it is impossible to secure complete separation within a reasonable time by pressure reduction alone in excess of 80 per cent of saturation, provided the water is refrigerated to prevent vapor evolution. This is primarily a question of apparatus, since vacuum pumps of types which permit of this experiment are invariably of low volumetric capacity at extreme vacua.

It was found early in the experimental work that water in pipe lines and in small streams unpolluted by sewerage is likely to be supersaturated with air. It was accordingly necessary to analyze water both before and after entering the process to get the measure of the results accomplished. Entering water temperatures fell continuously within the range of 38 deg. fahr. to 70 deg fahr., but did not in the least conform to solubility-table values of dissolved gases. It is significant of the physical phe-

nomena underlying the method that at low degrees of separation (70 to 95 per cent) the test results indicate a definite degree of separation rather than the reduction of dissolved gas content to a definite small value. At separation values much in excess of 95 per cent, the quantity of gases remaining is so exceedingly small that accuracy of testing is a limiting feature in extending such a conclusion into this range. It is the writer's frank opinion that the flat asymptotic portion of the curve in Fig. 3 represents complete separation of gases, but it is impossible to prove it.

Fig. 4 presents data on oxygen separation plotted as a function of separator vacuum with a constant separator temperature gradient of 22 deg. fahr., and illustrates the effect of variation of pressure. The separator temperature gradient of 22 deg. fahr. was selected as the minimum value that could give maximum separation. This curve is plotted in terms of dissolved oxygen because dissolved oxygen only was determined, the methods of testing for dissolved air being too inaccurate to apply over the major part of the range. It is, however, probably of equal applicability to dissolved air.

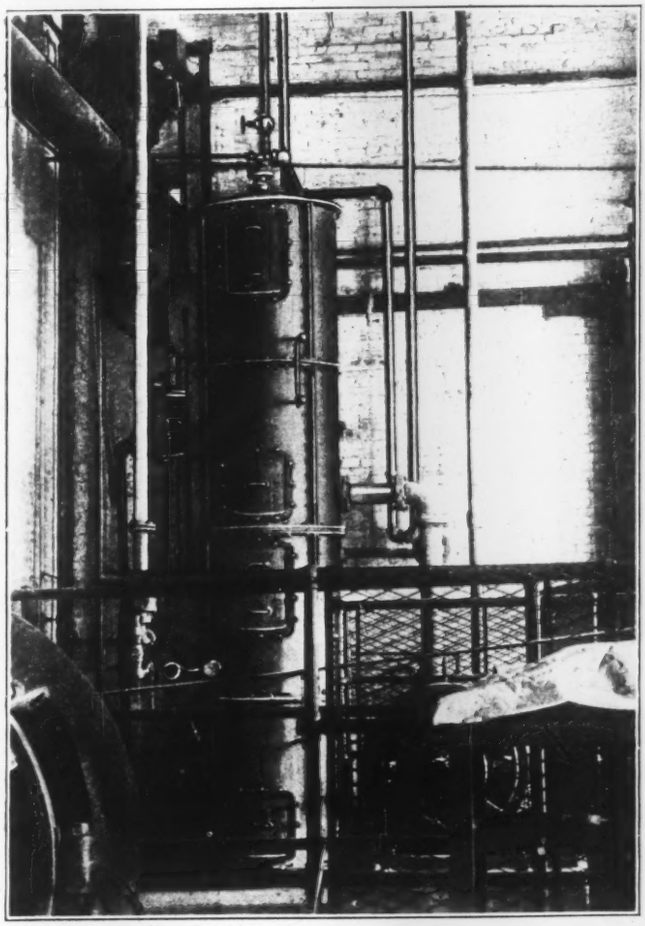

FIG. 2 INTEGRAL VERTICAL-UNIT COMMERCIAL INSTALLATION

The actual operation of a separator equipment is altogether as simple and straightforward as it can conceivably be. At a constant vacuum and admission temperature the water delivered by the separator is in exact equilibrium with the vapor-pressure temperature of the vacuum, and the increase of pumping head is exactly measured by the pressure head corresponding to the vacuum. The amount of heat in the vapor mixture and the amount of condensed vapor to be handled by the condenser can be calculated from the heat drop in the separator, and is constant at any specified rating. The circulation ratio in the condenser, which handles all the supply water in its cooling circuit, is constant for all rates of flow. Neglecting radiation, heat losses are substantially zero. The arrangement of exhauster and condensing equipment can be made sufficiently flexible to meet all conditions of application. Where a steam ejector is used, however, it is desirable to subdivide condensing capacity, using one section to condense the vapors withdrawn from the separator to relieve the ejector of the duty of evacuating them, and the other section to recover the heat of the ejector steam. The theory of the steam ejector seems best satisfied by the assumption of an entrainment and velocity compression of an inelastic fluid, making no concessions for the intrinsic energy of the fluid compressed, and a very slight one for differences of entrainment with variations in density. An ejector handling the vapor mixture from the separator under a 10-in. mercury vacuum has approximately five times the steam consumption of an ejector evacuating only the air. There are no moving parts in the apparatus except the float level control valves in heater and separator.

Careful tests were made upon the two heaters which at different times supplied the separator. The heaters were of a standard induction open-heater type, with spray pans for agitating the water in its passage through the steam. The vent openings, which were standard with the manufacturer, were freely connected to the atmosphere. Both of these heaters were able to deliver their rated capacity (300 and 1000 boiler hp.) of water with a 2-deg. fahr. temperature drop on atmospheric steam. Water was taken from below the water line of both of these heaters by a slow, large volume displacement into special apparatus and was tested for air without releasing the pressure or lowering the temperature. These tests gave reductions of dissolved air of only from 10 to 20 per cent, but when a similar sample was collected by rapid displacement in an open bottle, results indicated from 60 to 70 per cent at 212 deg. fahr. and a maximum of 78 per cent at 224 deg. fahr. Within this range of temperature, water within the 300-hp. heater viewed through a glass window in a blank-flanged connection against a submerged incandescent lamp bulb, appeared to be milky with entrained air bubbles. While any generalization from such meager data as these would be presumptuous, the writer cannot help but feel that from the standpoint of dissolved-air separation the heating of water from mixture with steam is an essentially different proposition from heating from a submerged and wetted source in the matter of temperature gradient within the body of the liquid. These conclusions apply specifically to a heater of the induction type, and probably would be very different for a "through" heater with its greater venting.

This work was undertaken as an industrial-research problem with the expectation that it would have two distinct fields of usefulness: the elimination of boiler and economizer corrosion in boiler plants, and of that of the entire distribution system in central-station heating, and the improvement of conductivity in surface condensation of steam. It developed in the course of experiments that it had additional merit in the removal of dissolved and half-combined carbon dioxide. The matter of corrosion has always received wide attention from the engineering profession and a vast amount of investigational work has been done on it. It was accordingly assumed at the beginning that a recapitulation of existing knowledge was all that was needed to establish the pernicious effect of dissolved oxygen. In the field of surface condensation and the removal of scale-forming materials, however, it was realized that direct experimental proof must be submitted to carry any conviction.

## CORROSION

Of the gases dissolved in water, nitrogen is altogether inert, hydrogen is inert except in the ionic form, while oxygen and carbon dioxide are the agents producing boiler and economizer corrosion. Similarly, among the dissolved solids magnesium chloride and soluble nitrates are to be included. Some waters, dependent upon locality, contain hydrochloric acid, and are included in the same category. Irrespective of the direct agent, however, all cases of boiler or economizer corrosion are ultimately either those of oxygen oxidation or of electrolytic currents. The ionic notation is the best vehicle for explaining the mechanism of the oxidation process, and in the complete paper recourse is had

thereto to demonstrate that dissolved oxygen and dissolved carbon dioxide, both of which are removed by the process, are responsible for the dangerous features of boiler and economizer corrosion: the former by destroying the inhibitive polarization and displacing the equilibria of the inevitable slight solution of iron in water; the latter by increasing the concentration of hydrogen iron and with it the initial tendency of the iron to dissolve.

Carbonic acid contributes to the acidity of boiler waters and, as a corollary, to the electrolytic action, and, being volatile, mingles with the steam. In this sense whatever portion of it that returns with the condensate is cyclic in its effects. From its ability to dissolve ferrous carbonate as ferrous bicarbonate it tends to concentrate all the products of pipe-line corrosion in heating systems in the boiler itself, and makes the apparent boiler corrosion much greater than it really is. Certainly it is a very undesirable constituent of boiler waters, but not nearly so dangerous as dissolved oxygen.

A high-pressure steam boiler is so complicated a chemical factory that there can be no general panacea for its ailments, but it is thought that the removal of dissolved oxygen and carbon dioxide is a decidedly effective step in the elimination of corrosion. Since it is a basic attack at the root of the evil, it will contribute to the success of all methods of eliminating corrosion which engineering experience has found good, but as long as boilers are made of iron and fed with water, some corrosion is inevitable. Boiler compounds, alkalinity, electric potentials, etc., are involved with such an infinitely variable condition of equilibria within the boiler that their success in practice can only be partial, while the effect of the removal of dissolved gases is aimed at the equilibria conditions themselves and is self-regulating.

The internal corrosion of economizer tubes is a phenomenon closely parallel with that of the corrosion of boilers. The corrosion here is more severe and localized and the corrosion products

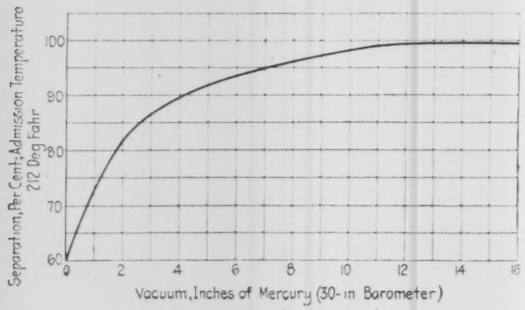


FIG. 3 RELATION BETWEEN AIR SEPARATION AND VACUUM

more alarming to the eye, although this is due primarily to a superficial change in the water of crystallization of the resulting hydrated iron oxides. The increasing cost of coal is bound to increase the use of economizers, but unfortunately both the cast-iron and the steel-tube types are unfavorably regarded, the former because of its uncertain factor of safety and the latter from its liability to corrode. Necessity, however, has already developed the steel-tube economizer closely along the type of header and tube construction used in boilers, and economizer boiler units are now available which show a decided increase in evaporative efficiency and reduction of cost over straight boiler units. The removal of carbon dioxide and oxygen will undoubtedly prolong the life of cast-iron economizers greatly, and will make the installation of steel-tube economizers economically practical and conservative. On this basis the gas-removal process will have technical significance in the future greater than it has at present.

## SCALE PRECIPITATION

Carbon dioxide exists in water as carbonic acid ($H_2CO_3$), which is capable of combining with carbonates to form bicarbonates; thus,

$$Ca(CO_3) + H_2(CO_3) = CaH_2(CO_3)_2$$

The carbonates of calcium and magnesium are soluble in the proportions of 23 and 106 parts per million by weight as carbonates, or, in other words, in water free from carbon dioxide, but soluble as bicarbonates in any proportion in which they are apt to exist in natural waters. Bicarbonates of either of these elements are metastable and readily part with their carbonic acid under the conditions existing in the separation equipment, being reduced to carbonates and precipitated in excess of their solubility values. Sodium carbonate and bicarbonate are soluble in all proportions, although half-combined carbon dioxide is also removed.

The air-separation equipment has been tried out on two waters; one from the water mains of the city of Pittsburgh, which had been drawn through a filtration plant from the Allegheny River; the other from a small local stream that supplies the Jeannette,

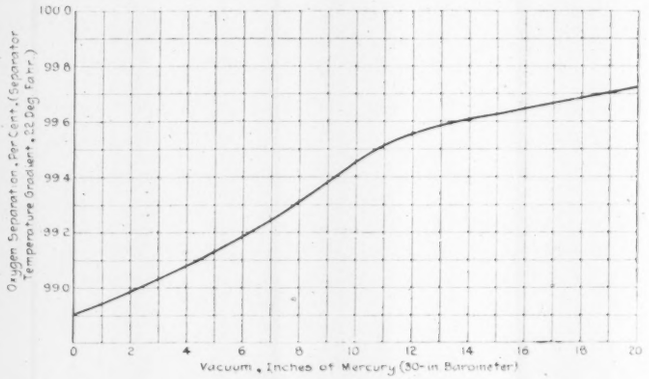


FIG. 4 RELATION BETWEEN OXYGEN SEPARATION AND VACUUM

Pa., works of the Elliott Company. Both waters were from the same water shed and had the same general analysis.

| | Allegheny City of Pittsburgh Parts per million | Surface Stream Jeannette, Pa. Parts per million |
|---|---|---|
| $CaCO_3$ | 24.92 | 15.7 |
| $CaSO_4$ | 130.53 | 18.2 |
| $MgSO_4$ | 4.59 | 15.7 |
| NaCl | 3.63 | 3.5 |
| $Na_2SO_4$ | 1.87 | 6.6 |
| $FeSO_4$ | 9.14 | 3.0 |
| $Al_2SO_4$ | 19.07 | 18.3 |
| NaOH | 4.94 | 0.0 |
| Organic volatile | 27.00 | 12. |
| Total | 225.09 | 93. |
| Total as determined | 214.0 | 87. |

The effect of the process in eliminating calcium carbonate was initially discovered by the soap titration test of Clark on a cooled and decanted sample of water which had been put through the process. It was difficult, however, to determine the dilution of the water with exhaust steam in the heater, and results from the method were only indicative. Careful gravimetric tests over the period June 1 to November 1, 1919, supplemented by careful volumetric titrations with phenolpthalein and methyl orange indicators, gave a uniform series of results running from 18 to 25 parts per million of $CaCO_3$, which agreed closely with solubility values. While exhaust-steam dilution appeared also in these results, the reduction was greater than could possibly be accounted for by dilution, and agrees closely with solubility values. The water after passing through the separation process invariably gave a pink color with phenolpthalein, although it gave no coloration before, indicating thereby the elimination of free carbon dioxide. Technical boiler water analysis is, however, so much a matter of hypothesis that such results as the foregoing may be regarded as confirmatory but not conclusive.

Calcium carbonate precipitates out of the hot solution of the process as a colloid, which coagulates very rapidly into a flocculent precipitate and becomes granular by the time it arrives in the boiler, where it is deposited as sludge. Scale taken from the boilers during the operation of the separation equipment gave only traces of calcium carbonate, although the sludge from the bottom

of the boilers contained a sufficient amount of it to be effervescent when treated with acid. No trouble was ever experienced from scaling of the boiler feed lines.

### Surface Condensation

The surface condensation of steam involves three distinct physical steps: the conduction of heat through a definite thickness of metal—the tube wall; and two boundary conditions, the transfer of heat from a vapor to a metal, and the transfer of heat from a metal to a liquid. In the surface condenser this latter condition is dependent upon the velocity, viscosity and temperature of the cooling water and the laws of the heat transfer are not definitely understandable. The other boundary condition is complicated in practice because the area exposed to steam flow is surrounded by a rarefied air film so that in reality two heat transfers are involved: from the steam to the air film and from the air film to the metal surface. The elimination of this film of non-condensable gas and the attainment of an ideal boundary condition is all that the air separation can possibly attain. It is to be expected that it will increase the conductivity by eliminating the resistance of the air film and increase the vacuum by reducing the partial vapor pressure; but the intricacy of the experimental data is very apt to obscure the simple physical fact involved.

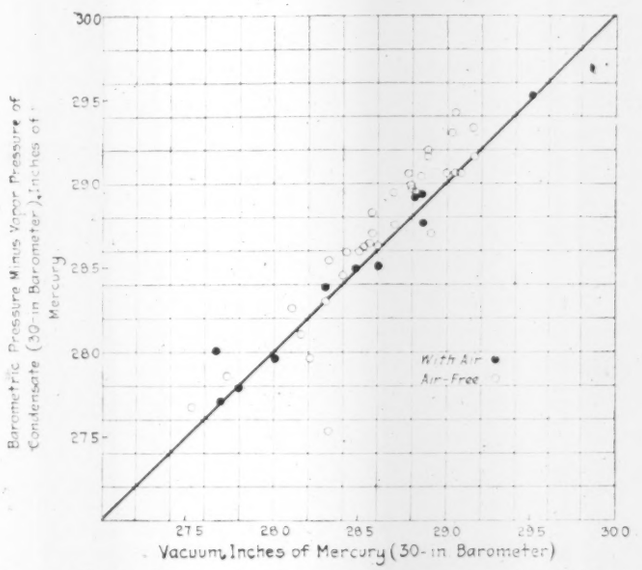


Fig. 5 Relation between Barometric Pressure Minus Vapor Pressure and Vacuum

In the experiments on surface condensation the boilers were fed with water which had been put through the air separation process and which was practically air free; and high-pressure steam was conducted to a cast-iron baffled cone bolted to the steam inlet of the condenser, expanded to condenser pressure, and allowed to enter the condenser with considerable velocity but no impingement. Two surface condensers of very dissimilar types were tested under these conditions. The first was of an antiquated type designed for engine service. The second was one furnished by the C. H. Wheeler Manufacturing Company after a design which had been built for the Bureau of Mines for experimental purposes, and was the type of unit that would ordinarily be furnished for a 100-kw. turbine. It consisted of 228 tubes, $\frac{5}{8}$ in. O. D., No. 18 B. W. G., with an active length of 8 ft., arranged in three water passes; calculated area, 301.7 sq. ft. It was furnished with a steam baffle and air-pump suction baffle, and was without rain plates, steam lanes or differential spacing. It was equipped with a motor-driven centrifugal condensate pump with condensate-water-sealed glands, and a 16-in. by 18-in. Rotrex dry-vacuum pump. This pump was separately motor-driven at constant speed, was arranged for separate sealing water injection, and at its operating speed had a volumetric capacity of 63.3 cu. ft. per min.

Vacuum was measured at the air-pump suction and at the nozzle, a special gage being made by welding a connection to the top of a U. S. Weather Bureau mercurial barometer. The air entering the top of the mercury column was chemically dried, the vacuum was never released, and the piping was all of copper tubing. This gage had a reading accuracy of 0.01 in. of mercury, and it is felt that the accuracy is consistent.

A thermometer well was inserted into the air-pump suction in the hope that it would furnish a check on the gage. The curious situation developed that, while a thermometer well drilled in a flange of the pipe wall which was insulated with hair felt maintained within 0.1 deg. fahr. of the temperature of the vacuum, the thermometer well projecting into the pipe showed a temperature several degrees higher at extremely high vacuum (i. e., 0.01 to 0.05 in. of mercury of the theoretical absolute) and equaled the temperature of the pipe at lower vacuum. The only plausible explanation was that the air particles were carried along in the rarefied vapor stream with a translatory motion but with a pressure so close to zero that all sensible molecular vibratory motion had ceased.

The temperature of the condensate was measured by a thermometer well immediately below the exit from the condenser, mercury-filled and equipped with a certified thermometer reading to 0.1 deg. fahr. With the centrifugal pump the condensate removal was continuous. Heat transfer was determined from the temperature rise and weight of cooling water. Cooling water was delivered under constant gravity head through a regulating valve, and after going through the condenser passed through a baffled weir box and over a 90-deg. weir. This weir was sharp-edged, cut from $\frac{1}{8}$-in. brass plate and mounted against a rigid iron frame with a commercially plane surface.

A method of checking this heat transfer was adopted which is curious in that it was successful, although the apparent odds against it were rather high. Steam was admitted to the expansion valve on the condenser after having been throttled from boiler pressure to 85 lb. gage by an automatic reducing valve, and in its passage from the boiler to the reducing valve the quality was measured. The condensate for an entire test was weighed in a large weighing tank. The sealing water from the air pump was weighed, its temperature rise measured, the amount of condensed steam calculated, and the amount of heat withdrawn with the air-pump vapors determined. The expansion of the steam into the condenser was assumed as one of constant heat content. This obviously did not represent the actual nature of the expansion, yet it was difficult to conceive of an appreciable quantity of heat being lost in the process. This heat value of the steam was corrected for initial quality, heat withdrawn by the condensate and by the air-pump vapors, but no correction was applied for radiation from or to the condenser shell. From this calculation heat transfer was computed and compared with that obtained from cooling-water measurement. The agreement between these values is the part that is curious. In a total of 52 tests the maximum difference is 35 per cent, the agreement perfect in two instances, and the average difference 7 per cent. The conductivities varied from 129 to 949 B.t.u. per sq. ft. per hr. per deg. fahr. difference in temperature.

In order to provide for as precise a comparison as possible between tests with air and those without air, a series of tests was run in which air was not extracted from the water before it entered the boiler, although it was heated up to atmospheric temperature in the open heater of the separation equipment. Air was not admitted directly into the condenser because no means of measuring the quantity admitted was known which would be of consistent accuracy with the remainder of the experiments. Such tests as either of these series are evidently not representative of operating conditions, in that they were performed upon a condenser of air-tightness far in excess of anything attained in commercial operation. They are an attempt toward an ideal condition of condensation, however, and are offered as being of specific interest because they apply to an actual condenser.

On account of the volume of the data of these tests, some 3400 tabular values, it is not practicable to publish the complete log in the present paper. However, a specimen log of two tests condensed to about one-third of its original volume is given in Table 1 for the use of those who wish to make a numerical comparison between the two groups, and the remainder of the data is presented in the form of curves, between such groupings of coördinates as are conventional in the representation of condenser tests.

It appears to be impossible to raise conductivity without recourse to methods that are freakish. Most of the heat transfer in the air-free tests took place in the upper tube banks; the transfer of heat was enormous, but without the additional refrigerating effect of the lower tubes it would have been impossible to secure

TABLE 1 SPECIMEN LOG OF TESTS (CONDENSED)

| | Separated | With Air |
|---|---|---|
| Date | 8/23/17 | 8/23/17 |
| Duration, hours | 1 | 1 |
| Barometric pressure, inches Hg | 28.96 | 28.98 |
| Condensate, lb. | 2,988 | 3,201 |
| Condensate, lb. per sq. ft. per hr. | 9.91 | 10.61 |
| Condensate temperature, deg. fahr. | 89.1 | 87.1 |
| Temperature cooling in, deg. fahr. | 67.8 | 64.2 |
| Temperature cooling out, deg. fahr. | 82.8 | 80.4 |
| Heat rise, cooling, B.t.u. | 14.96 | 16.16 |
| Weir head, ft. | 0.682 | 0.682 |
| Weir volume, cu. ft. per min. | 5.852 | 5.852 |
| Specific weight, lb. per cu. ft. | 62.20 | 62.23 |
| Weight cooling, lb. per min. | 3638 | 3640 |
| Weight cooling, lb. per hr. | 218,322 | 218,424 |
| Total heat to cooling, B.t.u. | 3,266,097 | 3,538,469 |
| Mean temperature difference log. deg. fahr. | 76.7 | 73.6 |
| Vacuum in condenser, inches Hg | 28.60 | 28.57 |
| Temperature of vacuum, deg. fahr. | 89.5 | 90.2 |
| Absolute pressure in condenser, lb. per sq. in. | 1.40 | 1.43 |
| Heat transfer, B.t.u. per sq. ft. per hr. per deg. fahr. | 846 | 706 |
| Vapor pressure of condensate, inches Hg | 28.62 | 28.70 |
| Cooling-water velocity, ft. per sec. | 8.47 | 8.47 |
| Cooling-water ratio | 75 | 68 |

a satisfactory vacuum. With the necessary refrigerating area the apparent conductivity was decreased.

The following data are significant of the range covered by the tests as a whole:

| | Maximum | Minimum |
|---|---|---|
| Condensation rate, lb. per sq. ft. per hr. | 18.87 | 2.82 |
| Cooling-water ratio | 174.5 | 8.7 |
| Cooling-water velocity, ft. per sec. | 11.94 | 2.77 |
| Cooling-water temperature, deg. fahr. | 90.9 | 35.0 |
| Cooling-water rise in temperature, deg. fahr. | 122.5 | 6.8 |

Fig. 5 is plotted between barometer minus the vapor pressure of the condensate as ordinates and vacuum as abscissæ, a solid line representing equilibrium being drawn thereon. The refrigerating effect is very decisively indicated. The condenser circulation was contraflow, three-pass, and in the air-free tests no transfer could be detected in the first pass. Simultaneously the vacuum drop in the condenser fell from 0.2 in. of mercury for 5000 lb. condensation per hour and 29-in. vacuum air to zero at all rates up to 5700 without air. Unfortunately these data were not systematically taken, since it was not known at the outset just where the advantages of air separation would appear. Ordinarily with steam-air mixtures and very efficient air removal from the condenser the phenomenon is exactly reversed, the maximum rise and the maximum transfer taking place in the lower tubes. It was possible by closing a valve in the air-pump suction to operate the condenser easily for an hour with a drop of 0.05 in. of vacuum at vacua as high as 29.06 in. When the valve was closed the condensate temperature immediately came into equilibrium with the vacuum. When, however, the loss of vacuum amounted to 0.1 in., the further drop was very rapid, amounting to a complete loss in about 10 minutes. The law of loss of vacuum was not definitely determined, but it was never a straight-line function of the time. Under the conditions of condensate removal there was never any opportunity for "drowned" tubes.

The tightness of the condenser was maintained by three methods: filling the steam space with water under pressure and watching for leaks; filling with compressed air under a pressure of about 10 lb. per sq. in. and painting with soap suds; and pump-down tests with a laboratory high-vacuum pump. If pump-down tests showed a leakage greater than 0.1 in. mercury per hour, tests were never performed. Loss of vacuum under pump-down conditions was always a straight-line function of the time over a period of several hours. Curiously, however, tests on the condenser operating with air-free steam showed higher vacuum than it was possible to secure on pump-down tests, and the loss of vacuum in such operation followed an entirely different law.

Fig. 6, giving relation between condensate depression (temperature of the vacuum minus temperature of the condensate) and conductivity, shows again and more pronouncedly than Fig. 5 the effect of refrigeration in the lower tube banks.

## CONCLUSIONS

A careful consideration of the data of these tests in all their phases has led the writer to the following conclusions, the basis for forming which he has unfortunately not been able to make altogether clear:

*a* A comparison between individual tests on air-free steam and steam with air which are sufficiently alike in the variable quantity values or which it has been possible to reduce to a satisfactory basis of comparison, indicates an increase in conductivity of about 20 per cent, figured upon the entire area of the condenser.

*b* It is possible to reduce the air component of the vapor pressure in a tight condenser to within an immeasurable amount of zero, and simultaneously eliminate all dead areas in the condenser due to air blanketing.

*c* The fundamental problem in condensation of air-free steam is not to conduct the heat but to get rid of it after it is conducted.

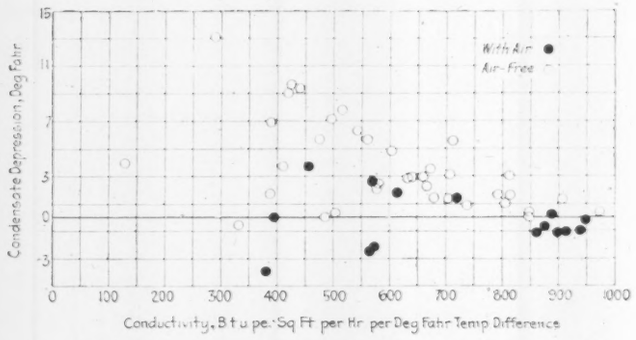


FIG. 6 RELATION BETWEEN CONDENSATE DEPRESSION AND CONDUCTIVITY

The economical limit of permissible hydraulic losses will limit conductivities to substantially the values that are used in commercial practice today.

*d* In the condensation of air-free steam two processes are involved: the actual condensation and the refrigeration of the liquid, which take place in different zones and are distinctively different processes. One process disposes of the heat and the other produces the vacuum, and each is therefore as indispensable as the other. In the zone of condensation heat transfers reach enormous values. In the zone of refrigeration both heat transfer and heat available are very low, and the conduction is from a liquid to a liquid. In this zone a very close spacing of tubes is permissible, and any change in design which would substitute water films for water droplets would be a constructive improvement. It is possible to isolate from the data of the tests the fact that the zone of condensation is limited at least to 30 per cent of the tube area, and the reduction of vacuum loss indicates it to be much less. The ratio of temperature rise between the different circulating-water passes is radically altered from operation with very slight amounts of air.

*e* From the radically different rates at which heat is transmitted in the different zones, it is impossible in tests on condensers of different types with air-free steam to arrive at any data from which to formulate or verify laws on the conduction of heat. Neither is it possible to apply such laws without an empirical assumption on the distribution of heat between the various tube banks. These tests, while they truly represent the condensation of air-free steam, contribute no information on numerical values of actual conductivities.

# A Stoker for Burning Eastern Coals

## Particulars Regarding a Newly Developed Stoker of the Conveyor-Feed Type in Which Forced Draft is Employed and High Rates of Burning Are Obtained

By L. R. STOWE,[1] ST. LOUIS, MO.

*It is well known that the chief difficulty in burning eastern bituminous fuels on chain-grate stokers is due to the fact that they cake or coalesce under the arch, and thus prevent the entrance of air through the fuel bed and check combustion. As a result of two years of experimental work a stoker has been developed by the Laclede-Christy Clay Products Company which, it is claimed, may be used satisfactorily with eastern bituminous fuels. This stoker, which the author describes, is of the conveyor-feed type and operates with mechanical draft. High ignition temperatures are employed, the air supply is graduated from feeding end to discharge end, and the fire is thickened at the point of ash discharge, all of which is said to result in the prevention of caking, the assurance of a CO content of from 10 to 12 per cent and an intimate mixture of air with the combustible gas. Further, rates of burning up to 60 lb. per sq. ft. of grate area per hour are obtained, as compared with the 25 to 35 lb. on chain grates, and the percentage of combustible in the ash is reduced 50 per cent.*

FOR the past two years the Laclede-Christy Clay Products Company has been experimenting on a new forced-draft stoker for use with the various kinds of fuel found in this country. The stoker used employs the conveyor method of feeding, i. e., progressively moving chain-grate conveying elements feed the coal through the furnace and discharge the refuse to the ashpit. Fig. 1 shows the test boiler and stoker.

The feature of the conveyor feed that commends its use is its handling of the fuel bed in a positive, definite fashion. By striking off the fuel evenly under a feed gate and then literally carrying it on through the furnace and over the point of ash discharge, this mechanism prevents in a large measure the evils of less positive feeding devices, namely, specifically uneven fires, balled-up spots, and immovable clinker formations. These advantages of conveyor feeding are very attractive to the stoker designer, and as a result of this and of the fact that the underfeeds have quite thoroughly demonstrated the great advantages of mechanical draft, many builders are now experimenting on and developing various forms of forced-draft conveyor-feed stokers. In fact, work in this direction characterizes the efforts of the stoker industry at the present time, and the following particulars regarding the experimental work of the Laclede-Christy Company and the results it has attained should therefore prove of timely interest.

For many years it has been quite clearly established that nearly every requirement of a successful stoker is lacking when burning caking fuels on chain grates with natural draft. The coal cakes almost immediately upon entering the furnace, high rates of burning cannot be secured, the combustible content of the ash is high, the admission of the air is not properly graduated to the requirements of the various stages of combustion, and maintenance of links is excessive. This is indeed a complete indictment, and with the sole exception that the automatic features are always in evidence, it may be said that the performance of chain grates on eastern bituminous coals violates every requirement of a successful stoker.

It is well known that the caking property of eastern coal is the most serious obstacle in the way of the successful use of this fuel on chain grates. In endeavoring to burn Pocahontas and similar coals it is observed that tarry oils flow through the fuel bed as a result of the application of heat at moderate temperatures. It is further observed that the coal under the arch is caked or coalesced by these tarry oils, and forms a sticky blanket that prevents the entrance of air through the coal and hence checks combustion and heat generation under the arch.

In attempting to remedy this situation the most natural thing to do is to employ mechanical means to break up the caked fuel bed, which is the course almost invariably taken by the inventor. In fact, the idea is prevalent that "A mechanical agitation of the fuel bed, for the purpose of breaking up the coke, is necessary or advisable when burning eastern coals." So many statements have appeared similar to the one just quoted that mechanical engineers have come to accept it as a basic fact. The results obtained at the experimental plant, however, have disproved this contention and in doing so have made possible the application of conveyor feeding to the burning of eastern coals.

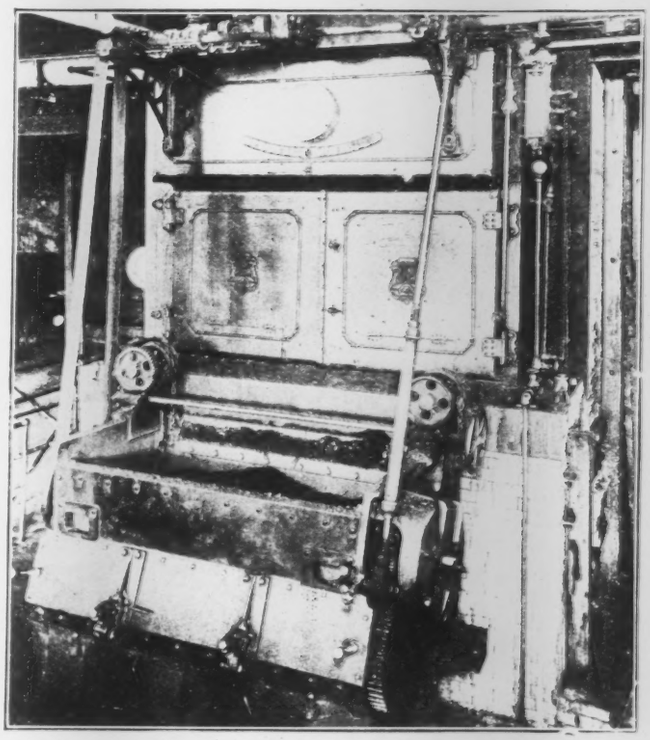

FIG. 1 THE TEST BOILER AND STOKER

In the experiments with this new stoker the ignition temperatures are extremely high and at these temperatures considerable amounts of air are forced through the fuel bed, thus providing for the absorption of sufficient oxygen in a short time to destroy the initial caking tendency. Moreover, it is reasonable to suppose that these unusually high temperatures at the same time cause a quite different procedure in the destructive distillation than that which obtains with lower temperatures.

The absence of coke formation has almost as marked an influence on the last half of the fire as on that portion under the arch, because since coke is not formed in the distillation zone the cemented coke lumps cannot be present in the final stages of combustion. The individual pieces of coal retain their identity exactly the same as when Illinois coal is used, with the result that the fuel bed has the soft, incandescent and fluffy appearance

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Abstract of a paper to be presented at the Spring Meeting, St. Louis, Mo., May 24 to 27, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Advance copies of the complete paper may be obtained gratis upon application. All papers are subject to revision.

which every chain-grate fireman realizes means economy and high rates of burning. The absence of coke formation in the final stages of combustion will be mentioned again.

## THE NEW STOKER

A description of the final apparatus decided on is advisable at this point for the purpose of showing how the high initial temperatures are attained. Fig. 2 is a view of the grate surface, its general incline being 20 deg. The arrows indicated by *A* point to narrow chain-grate or conveying elements, about 4 in. wide and placed on 7-in. centers. In the intervening 3-in. spaces are placed stationary tuyeres indicated by arrows at *B*. At the lower end of the grate surface the tuyeres *B* terminate in short pivoted bars *C* which are made automatically to rise above, then drop below the surface of the conveyor chains. This action takes place slowly. *D* is a feed gate, adjustable to give various thicknesses of fire exactly as on a chain grate. Partly overhanging the vibrating bars *C* is the bridge wall *E*, shown cut away in the center. An ignition arch is shown at *F*. This latter provision conforms to chain-grate practice except that with the greater incline of the grate the arch is farther away from the fire. Fig. 3 shows a cross-sectional side elevation of the stoker and boiler and Fig. 4 details of the conveying elements marked *A* in Fig. 2.

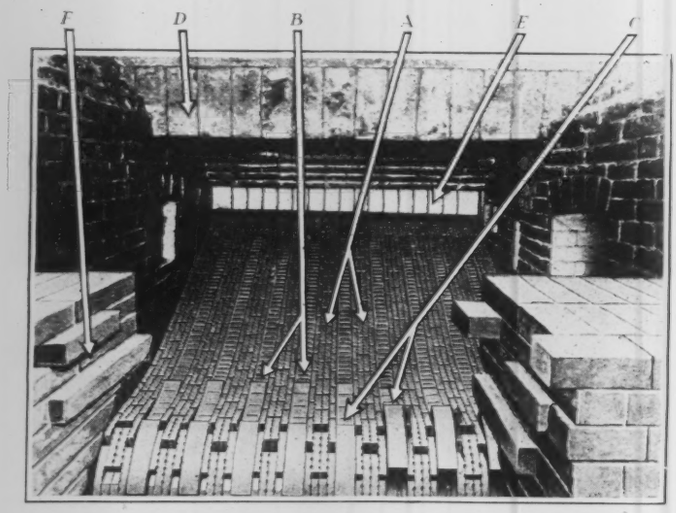


FIG. 2 VIEW OF THE GRATE SURFACE AND FURNACE TESTED

Close study of chain-grate practice has revealed much in the art of building up high ignition temperatures. A great expanse of bridge wall extending from a point horizontal with the arch to or nearly to the fuel bed is known to be of utmost value in directing heat on to the incoming fuel. This is the surface indicated by *A* in Fig. 3. The steep incline of the stoker in question permits this dimension *A* to be greatly extended over that possible with the ordinary chain grate. Moreover, it exposes the fuel bed more directly to the intense heat reflected from the bridge wall and the flame in front of it.

The form of arch was also taken from chain-grate practice and its design and placement has, of course, contributed its part toward the building up of the high fuel-bed and ignition temperatures that play so important a part in preventing the caking and ultimate coking of the fuel.

In view of the troubles known to exist with eastern fuels when using a stoker that conveys the fuel undisturbed into the furnace, the author deems it advisable to give a further description of the stoker in question in the light of what is required today in the economical burning of coal for the generation of steam, touching particularly on those features that have been prominently wrong with chain grates. The following outline presents the entire situation at a glance, and later in the paper each of the items therein is briefly touched upon.

PRESENT-DAY REQUIREMENTS OF AN AUTOMATIC STOKER COMPARED WITH THE PERFORMANCE OF CHAIN-GRATE AND CONVEYOR-FEED STOKERS—EACH USING EASTERN COALS

| | Requirements of the Present-Day Stoker | Results Obtained With Eastern Coals | |
|---|---|---|---|
| | | With Chain Grates | With Conveyor-Feed Stoker Described |
| 1 | It should completely burn all combustible that arises from the grate and perform this task under the great handicap of using no more air than is required. | Thin fires spotted with upstanding coke result in excess air and low $CO_2$ due to the fact that the air supply is not graduated down to a minimum at the rear of the stoker and to influences attending the coking of the fuel bed. | Graduation of air supply and thickening of fire near point of ash discharge and prevention of coke assure a consistent 10 to 12 per cent. $CO_2$ content with positive assurance of an intimate mixture of air with combustible gas. |
| 2 | It should bring about low combustible in the ash. | Combustible in the ash from 30 to 50 per cent. | Combustible in the ash from 16 to 24 per cent. |
| 3 | It should burn coal at high rates of burning—not only, to obtain high capacities but to widen the range of economical rates of burning as well, that great flexibility may be assured. | Rates of burning from 25 to 35 lb. of coal per sq. ft. of grate surface per hour. | Rates of burning up to 60 lb. of coal per sq. ft. of grate surface per hour. |
| 4 | It should be as nearly wholly automatic as possible in operation. | Successful in the matter of automatic operation | Successful in the matter of automatic operation. |
| 5 | It should not entail unreasonable expense in the upkeep of the grate surface or of the furnace brickwork. | No unusual maintenance cost for furnace brickwork, but a very high one for grate links. | Use of mechanical draft imposes a more severe condition for furnace brickwork, requiring a higher grade of refractories, but maintenance of ironwork is not excessive—in fact, may be considered quite satisfactory |

It is of interest to note that the difficulties with chain-grates on eastern coal have been violations of the essential requirements of the modern stoker, so it is not surprising that the opinion prevails that success can not be obtained with eastern coals using the conveyor feed.

## AIR DISTRIBUTION

It will be generally admitted that one of the prime considerations, if not indeed the most important, in requirement No. 1 above, is that each particle of combustible (whether solid, vapor, liquid or gas) as it leaves the grate shall be accompanied initially and primarily by its own quota of oxygen-giving air, and it will also be admitted that these combustible particles leave faster from some parts of the fuel bed than from others. The necessity of considering the most vital subject, air distribution, is therefore indicated.

Samples of the furnace gases from all parts of the fuel bed have been analyzed from time to time as succeeding designs of stokers have been put into use. A survey of these analyses pointed out that the greatest amount of air is required at the forward end of the stoker and that only a limited supply is advisable just in front of the point of ash discharge. The individual tuyeres are only 14 in. long and are made in several interchangeable patterns, differing only as to the percentage of their air space, which ranges from 2 per cent to 22 per cent. It is to be noted, therefore, that great latitude in the matter of air supply is possible for any stage of combustion in these experiments.

Table 1 shows the air-space distribution finally decided upon. This arrangement gives the most uniform condition of furnace gas thus far attained.

There is a rather gradual decrease in the amount of air space from the initial to the final stages of combustion between the two extremes indicated in the table. It is to be noted therefrom, moreover, that it has been found that more than twice as much air is required for the zone of destructive distillation as for the bed of well-spent fuel, and hence the advantage of graduating the air supply is readily apparent.

TABLE 1 AIR-SPACE DISTRIBUTION ADOPTED FOR CONVEYOR-FEED STOKER

| Air Space in Each Element at Feeding End | | Air space in Each Element at Discharge End | |
|---|---|---|---|
| Conveying elements | 8 per cent | Conveying elements | 8 per cent |
| Tuyere elements | 22 per cent | Tuyere elements | 2 per cent |
| 8 per cent of 60 per cent = | 4.8 per cent | 8 per cent of 60 per cent = | 4.8 per cent |
| 22 per cent of 40 per cent = | 8.8 per cent | 2 per cent of 40 per cent = | 0.8 per cent |
| Total air space | 13.6 per cent | Total air space | 5.6 per cent |

Conveyor elements—about 60 per cent of total grate surface
Tuyere elements—about 40 per cent of total grate surface

## Low Combustible in the Ash

One of the best ways of reducing combustible in the ash with the conveyor-feed type of stoker is to build up high ignition temperatures. In the initial stages, the coal burns from the top down, while during the latter stages the burning is reversed, the bottom of the fuel bed, where the air is richest in oxygen, being most active. The stronger or hotter the ignition temperatures, the quicker this reversal is effected, and if an early burning from the bottom up is established the combustible content of the ash will be materially decreased. The high ignition temperatures of the improved stoker have previously been referred to and their influence has unquestionably aided in reducing the combustible of the ash to a satisfactory amount.

With the caking and ultimate coking of eastern coals that occur with chain grates, the air breaks through the continuous mass of coke at the fissures or crazed places. The burning starts at these fissures and continues into the bed for its entire depth. This burning is at first quite rapid when the fissures are small, but as they increase in size the burning of the remaining coke slows down, due not only to the cooling influence of the bare spots but as well to the lessening intensity of the draft occasioned by the continual increase of the effective air openings. By reason of the original coked condition of the fuel bed, then, the fire in its final stages is characterized by bare spots and upstanding coke. To avoid exceedingly low $CO_2$ it is necessary to run these bare spots out of the furnace even though the spots of coke must be carried along with them. In other words, an effort to slow down the feed and burn the coke would result in a stack loss greater than the attending saving from burning the combustible from the ash.

With the coking of the fuel bed prevented and with each particle of coal preserving its identity in the last stages of combustion, the air filters through the innumerable interstices of the coal and causes the fuel bed to burn down evenly, giving that soft, intensive and highly luminous fuel bed that makes for high $CO_2$ in the gas and low combustible in the ash.

As to the retarding mechanism shown in Fig. 2, the short pivoted bars *C* in their lowest position allow the adjacent conveying elements to convey the ash from the furnace, but in their raised position they not only form an obstruction to the movement of the ash but raise the ash above the influence of the conveyor chains. The position of these bars with respect to the chains can be altered at the will of the operator to bring about any desired retarding influence.

The feeding at the upper end of the stoker is not affected by the retarding bars, and consequently while the ash is being positively held back of the point of discharge, additional ash-laden fuel is just as positively being conveyed toward the point of discharge by the positive feed from above. These actions result in a thickening of the fuel bed and in the squeezing out of any bare spots that may have formed. Thus it is seen that not only is the combustible given a longer period of time in which to be completely burned, but the fuel bed is thickened so that the air entering through it may be effectively used.

It appears to the author that a particular virtue of mechanical draft lies in the burning of the combustible from the ash, for at the start of this process we are dealing with an extremely poor fuel of which the ash content may be considered to be as high as 60 per cent. It is with this in mind that the stoker in question has been so arranged that the full pressure of the wind box is made effective throughout the last stages of combustion. The experiments have been so conclusive on this point that if in further experiments it is decided to graduate the air pressure under the grate, the greatest pressure will be provided where the ash content is the highest. Of course, because of the relatively small amount of combustible in the fuel bed less air is required, so that, as explained above, the air spaces under this part of the fuel bed are materially smaller than elsewhere.

Four matters, then, are of importance in burning the combustible from the ash of eastern coals with the stoker in question.

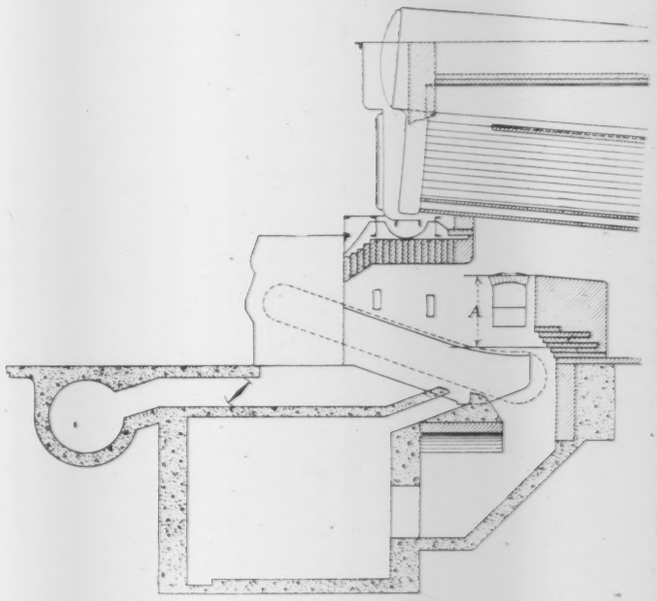


Fig. 3 Sectional Elevation of Boiler and Stoker

(The boiler has 2500 sq. ft. of heating surface and the stoker 40 sq. ft. of grate surface, giving a ratio of 62½ to 1.)

These are: (1) The influence of high ignition temperatures on the combustible content of the ash; (2) A fuel bed that may be said to be free-burning as compared to one characterized by a coking tendency; (3) The holding back of the ash and attending thickening of the fuel bed in the final stages of combustion; (4) Greater intensity of draft through the bed of nearly spent fuel.

## High Rates of Burning

Enough has already been said regarding the new stoker and its performance to make it evident that rates of burning with this type will be materially increased over those obtainable on chain grates using eastern coals with natural draft.

For instance, it is readily apparent that when the plastic, caking condition of the fuel bed is replaced by one that is free-burning and intensely active, the change will be very favorable to higher rates of burning. It is quite evident, too, that the application of forced draft will be an aid in this direction. It may be mentioned here that the chief means employed to obtain high $CO_2$ under forced draft have been (*a*) the air-distribution arrangement previously mentioned; (*b*) the retarding influence of the bars *C* together with the somewhat thicker depth of the general fuel bed over chain-grate practice; (*c*) the increased chemical activity of the fuel bed due to the higher fuel-bed temperatures;

and (*d*) the impinging of the air on the fuel bed through the employment of miniature air spaces.

### Automatic Operation

Having satisfied the first three requirements, this stoker must justify the use of the word "automatic"; that is, it must operate with the minimum of effort from the attendant. In this connection it is simply necessary to recall the basic principle of the conveyor-feed stoker—a positive feed from coal hopper to ashpit.

The only thing that interferes in the least with this entirely automatic and continuous operation is the clinker formation of the side walls. While this formation is no more serious than

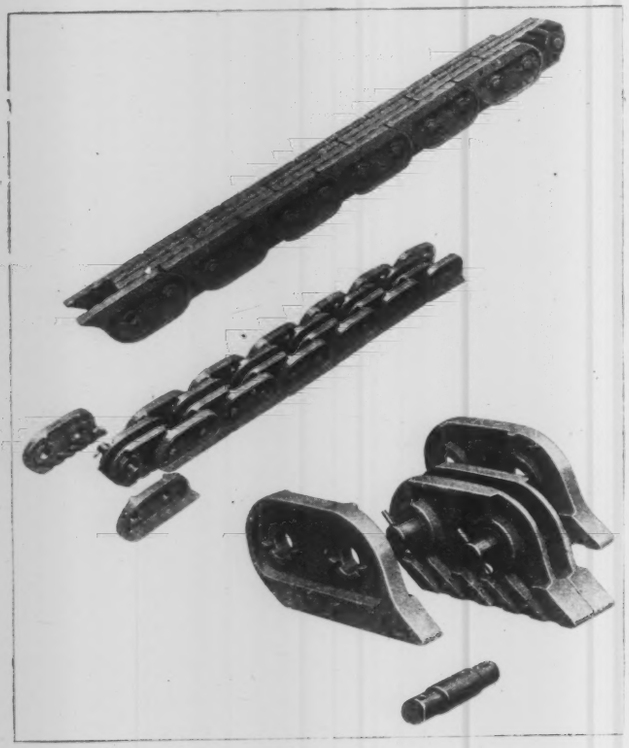

FIG. 4 DETAILS OF THE CONVEYING ELEMENTS MARKED "A" IN FIG. 2

with the chain grates, experiments are nevertheless under way in the experimental plant to minimize this evil.

As regards eastern coals, however, it may be of interest to note that they require less slicing of the side walls than do Illinois coals, probably because of the lower ash content and the higher fusing temperatures of the ash. Further, the eastern coals have a higher heat value and a greater firing stability than do Illinois coals, and consequently require less attention. And because of these advantages the firemen of the experimental plant much prefer on this new equipment eastern fuels to those of the Central West.

### Low Maintenance

All of the factors relating to the actual burning of the coal have now been discussed and there remains only the consideration of the matter of low maintenance.

Excessive maintenance of chain grate links when using eastern coals may in part be ascribed to the uneven burning of the fuel bed at the rear of the grate and to the low ash of these fuels. These two conditions combine to lay bare and expose the grates to the heat of the furnace.

Further, in an effort to build up a high $CO_2$ content in the escaping gases and thus exclude the thief, too much air, the boiler dampers are apt to be partially closed. This procedure may be effective in increasing the $CO_2$ and in raising the furnace temperatures, but it makes for a sluggish movement of the air over the faces of the links, thus reducing the cooling influence. It further causes the heat to penetrate down into the grate links instead of being carried briskly out of the furnace. An action of this kind, especially where stokers too large for the load are provided, produces in any stoker a condition under which no grate can permanently endure.

With a stoker of the type described the thickening up of the fuel bed, especially near the bridge-wall end, together with the high rates of burning, permits one with a relatively small area being employed. This same thicker fuel bed, too, may probably be considered the most important factor in protecting the links from the heat of the furnace.

The use of mechanical draft and small air spaces with the attending high velocity of air over the sides of the grates exerts a great cooling influence on the links even at moderate loads. Moreover, the links have been especially designed for this service. They are short, and much deeper than chain-grate links. They are free from any appreciable corrugations or flutings near the top face. Cooling veins extend deep down the sides of the links.

In the successive designs of stokers which led up to the one finally adopted, no one was operated for any appreciable time, but the links of the latest designs run so cool under both forced and natural draft that their low maintenance can easily be predicted. The maintenance of the tuyeres can only be determined by their extensive and prolonged use. But no deterioration of these or of the retarding bars has thus far been noticed and it is thought that the same influences that save the links will be more or less operative with the tuyeres, though due allowance must be made for the one important difference that the tuyeres remain continuously in use while the links as in the chain grate are used intermittently.

Regarding the maintenance of the brickwork, the higher rates of burning and the higher furnace temperatures of course impose more severe conditions. The maintenance due to mechanical draft, however, is not such as might at first thought be expected, for only a moderate air pressure (less than 2 in. water column) is used, and with the very small air openings occurring uninterruptedly across the entire width of the stoker, any impinging influence of the flame is lost quite near the surface of the fuel bed.

The problem of more severe furnace conditions has thus far been met by employing refractories of a higher grade. The side walls and bridge wall have been made with standard 9-in. shapes and the writer is advised that the higher refractoriness of the brick used is in part due to its higher percentage of alumina and its low content of fluxes.

Regarding the ignition arch, both the process and the mixture are new in stoker work. The material is highly refractory and porous and its performance under the harder usage bids fair to rival the ordinary arch maintenance in chain grates.

The essential points of this paper have been sufficiently marked to require no summary, but it may be said in closing that those connected with the experimental plant have derived considerable satisfaction in attaining the degree of success noted through the employment of such simple means.

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In a lecture on Some Obscure Points in the Theory of the Internal-Combustion Engine, given recently at a meeting of the Junior Institution of Engineers, Prof. F. W. Burstall said that as regards the combustion of gases in a metallic envelope, it would appear that most of the phenomena connected with afterburning can be explained when the variation of the specific heat with temperature is taken into consideration, but there still remains doubt as to whether or not combustion is complete at the point of maximum temperature. He feels that nearly all the experimental work which has been done on the internal-combustion engine has a most serious drawback from the point of view of the student of thermodynamics, namely, the number of variable quantities involved is so great that it becomes almost impossible to deduce any exact laws from a series of experiments. (*The Engineer*, March 12, 1920.)

# Locomotive Feedwater Heating

## Description of a New Type of Heater and a Discussion of the Advantages of Locomotive Feedwater Heating

By THOMAS C. McBRIDE,[1] PHILADELPHIA, PA.

*This paper describes a system of locomotive feedwater heating which makes use of the so-called open type of heater in which the exhaust steam comes into direct contact with the cold feedwater. The author describes the construction and operation of the heater and discusses the coal saving, water saving, and possibilities of increased capacity due to locomotive feedwater heating. These are dealt with first from a theoretical standpoint, and second from the practical standpoint, based upon the reports of actual tests. Tables and curves based on tests are presented and analyzed, and the paper is concluded with a discussion of the question as to whether the exhaust steam taken by the feedwater heater would cause trouble with the draft. From actual operating conditions the author states that "there was a surplus of exhaust steam left available for the draft."*

THE use of feedwater heaters on locomotives dates back to the beginning of the locomotive itself. There are records of the application of an open or injection type heater to a locomotive in England in 1827, and an English patent of 1828 describes a tubular heater for the same purpose. Ross Winans of Baltimore applied tubular heaters to two types of Baltimore & Ohio railroad locomotives in 1836. It is worthy of note that the desirability of the feedwater heater for the locomotive was recognized at these early dates, although it must be appreciated that the advantages possible at that time were proportionately greater than at the present time because of the low steam pressure then in use.

There is much of interest in the history of locomotive feedwater heating in a paper, Feedwater Heaters and Their Development, by J. Snowden Bell, which was presented at the fiftieth annual meeting of the American Railway Master Mechanics Association, in June, 1918. Every conceivable type of heater and all possible sources of heat, even the hot ashes, seem to have been proposed or tried, and in view of the amount of study that has been given to the subject it seems rather remarkable that locomotive feedwater heating is not now in more general use. Possibly the reason lies partly in the fact that it is only in comparatively recent years that the essentials of heater performance and pump operation have been understood.

There are two possible sources in a locomotive from which otherwise waste heat may be obtained to heat the feedwater. These are: (*a*) the waste gases in the smokebox or stack and (*b*) the exhaust steam.

The exhaust-steam heater may be either of the open or injection type in which the exhaust steam comes into direct contact with the cold feedwater so that the water condensed from this exhaust steam is added to and mixed with this feedwater; or, of the closed or surface type in which the heat from the condensation of the exhaust steam passes to the feedwater through thin sheets of metal, generally in the form of thin brass tubes. Practically all of the development work to date that has been at all successful has considered only the surface type. There are a great many heaters of this type in service in Europe, but there are objections to it for locomotive use. It is a complex and delicate structure. It wastes the water condensed from the exhaust steam with its heat or raises complications as, to saving it, and requires enough exhaust steam to heat all of the feedwater. On the other hand, the open or injection type of heater necessarily recovers both the water condensed from the exhaust steam and its heat so that both are returned direct to the boiler with the water taken from the tender. Less water is therefore taken from the tender and less exhaust steam is required for the heating.

### Description of a New Type of Heater

With these thoughts in mind, the author has devised a system of locomotive feedwater heating which makes use of a heater of the open type which is manufactured and marketed by the Worthington Pump and Machinery Corporation. The system follows marine practice in heaters of this type, and the pump and heater have been combined into a single unit which can be conveniently attached to the side of the locomotive boiler as is the practice with air-brake compressors. Fig. 1 shows a unit with a capacity of 60,000 lb. of feedwater per hour in service on a Mikado locomotive and Fig. 2 a sectional view of the heater and pump. In these illustrations the heater is shown at the left, the feed pump at the right.

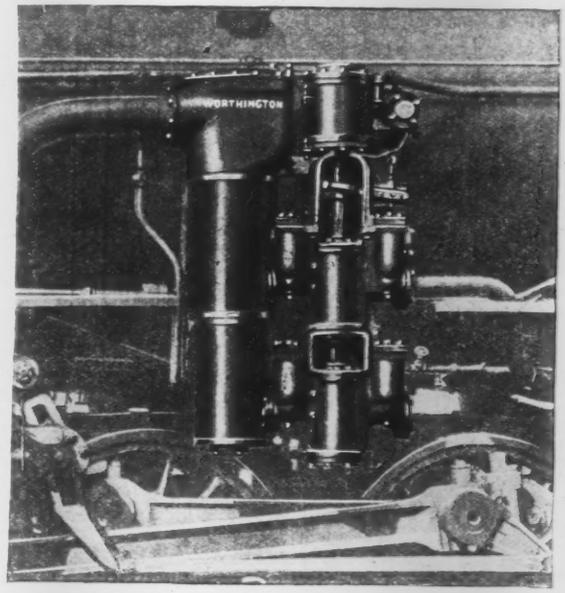


FIG. 1 PUMP AND HEATER APPLIED TO MIKADO LOCOMOTIVE

The heater is a simple cast iron box, the upper part of which is supplied with exhaust steam taken from the locomotive through holes cut in the back of the cylinder saddle and a pipe which has in it a stop check valve and an oil separator, the latter having a small hole in it so that there is a continuous drip for the oil.

The pump is of the vertical type attached to the side of the heater by the various pipe connections. The steam cylinder of the pump is at the top, and it has two water cylinders clearly shown in the illustrations, both operated from the same piston rod. The water cylinder in the middle of the pump takes cold water from the tender and delivers it through a port in the side of the heater to a spray valve in the extreme top of the heater where it is sprayed into the exhaust steam that fills the top of the heater. This condenses as much of the exhaust steam as the water needs to heat it, and the mixture, dropping to the bottom of the heater, is taken by the other pump cylinder and delivered to the boiler through the usual check valve.

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The pump is driven by saturated steam taken from the locomotive boiler through a 1-in. steam pipe and controlled by a throttle valve in the cab within convenient reach of the engineer. The exhaust steam from the pump is led into the back of the stop check valve where it mixes with the exhaust steam from the locomotive and passes with it through the oil separator to the heater.

The adoption of the open heater for the locomotive may seem a radical step, but from this description it will be evident that no new elements are used. The heater itself is of a general type that has been in use in marine service for at least twenty years. The open heater with the oil separator to remove the oil from the exhaust steam before it enters the heater because of its merits has been almost universally adopted for stationary plants. One of these heater and pump units was thoroughly tested out on the locomotive test plant of the Pennsylvania Railroad at Altoona, Pa., in 1917 and has been in operation on road service since October, 1918. Three more units have been in operation for

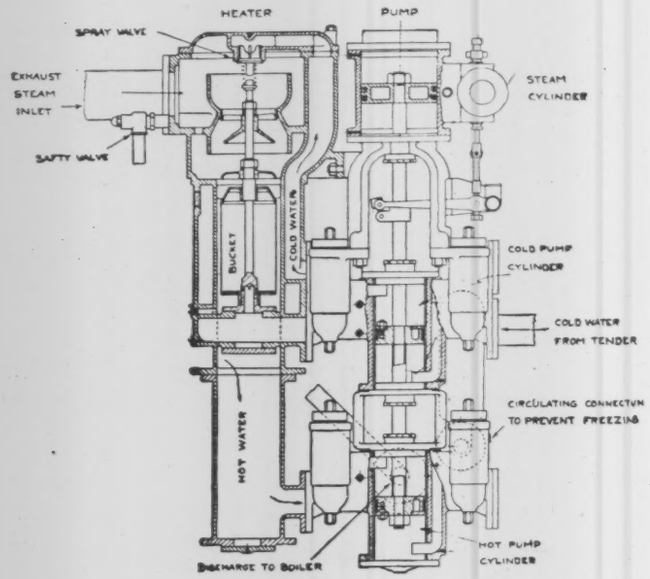


FIG. 2 SECTION OF THE HEATER

approximately a year on pooled locomotives and have given no trouble other than the usual pump maintenance. Nothing has developed indicating that the open heater as a type is not well adapted to the locomotive and the coal and water savings have been so marked as to be evident to the crew.

## ADVANTAGES OF LOCOMOTIVE FEEDWATER HEATING

It is not possible to make an exact general statement of the advantages to be obtained from locomotive feedwater heating because so much depends on the particular locomotive to which the heater is to be attached, the capacity at which it is worked, the temperature of the water in the tender, and the basis on which the advantages obtained are stated.

We are liable to base our notions as to the advantages of feedwater heating on the results obtained in stationary practice where the coal saving is very properly considered as equivalent to the reduction in the amount of heat necessary to evaporate the water because of the higher temperature at which the water is delivered to the boiler due to the heater. In the case of the locomotive, however, with its very complicated relations of the different operations that are going on and the very wide range of capacity through which the boiler is operated, there is generally a much greater coal saving than in stationary practice. Three factors enter into the final result. These are as follows:—

1. The reduction in the amount of heat required to evaporate the water in the boiler, which might be called the *heat saving due to the feedwater heater.*
2. The reduction in the amount of heat required results in a greater reduction in the amount of coal required because of the better efficiency of the boiler at the lower rate of combustion. These two factors give the *coal saving based on water evaporated.*
3. The exhaust steam taken by the heater from the exhaust ports of the locomotive reduces slightly the back pressure in the locomotive and should show some advantage. All three factors combined will give the *coal saving based on indicated horsepower.*

An analysis of these three factors will show the coal and water saving referred to the steam that is used in the locomotive cylinders, and therefore, the minimum saving since it does not include the saving in generating the steam used by the auxiliaries. It is necessary to make this analysis partly theoretical, assuming certain constant operating conditions in order that a fair comparison may be made of the effect of the heater on different locomotives and at different locomotive capacities. It can only apply to the coal burned while running since the heater can have no influence while standing or at terminals. The percentage of coal saving due to the heater, and to a lesser extent the percentage of water saving when based on ton miles, the month, or the year will be less than the percentage while running by an amount determined by the use made of the locomotives.

## HEAT SAVING DUE TO FEEDWATER HEATER

The first factor, the heat saving, is determined by the amount the feedwater is heated by exhaust steam taken from the locomotive. This factor will evidently be greatest when the tender water temperature is low and when the exhaust steam pressure in the heater is highest, as this pressure determines the temperature to which the feedwater can be heated. This pressure will be highest when the locomotive is working hard, and when the exhaust steam for the heater is taken from that part of the steam valve chests or cylinder saddles where its pressure is greatest.

Test-plant results and actual daily operation on the road with superheated steam locomotives show that the feedwater heater described can be depended on to effect a reduction of at least 10 per cent in the summer time and 12 per cent in the winter time in the amount of heat required to evaporate the water and superheat the steam. This heat saving will not be constant at these figures but will vary with the capacity at which the locomotive is worked because the steam pressure in the heater determines the temperature to which the feedwater can be heated. These figures can, however, be conservatively accepted as representing average working conditions at which the greater part of the coal is burned.

TABLE 1 HEAT SAVING DUE TO FEEDWATER HEATER

| | | | | |
|---|---|---|---|---|
| Assumed steam pressure in branch pipe, lb. per sq. in. | 200 | 200 | 200 | 200 |
| Assumed superheat, deg. fahr. | None | None | 150 | 150 |
| Assumed temperature water in tender, deg. fahr. | 40 | 70 | 40 | 70 |
| Heat content per pound of steam, B. t. u. | 1199.1 | 1199.1 | 1284.6 | 1284.6 |
| Heat content per pound of water, B. t. u. at 40 degrees | 8.0 | | 8.0 | |
| at 70 degrees | | 38.0 | | 38.0 |
| Heat required to generate one pound of steam B. t. u. | 1191.1 | 1161.1 | 1276.6 | 1246.6 |
| Heat saving in B.t.u. when water is heated from 40 to 215 degrees | 175.0 | | 175.0 | |
| 70 to 215 degrees | | 145.0 | | 145.0 |
| Heat saving, per cent | 14.7 | 12.5 | 13.7 | 11.6 |
| Total heat required by locomotive with feed pump, as compared to injector operation, per cent | 102 | 102 | 101.75 | 101.75 |
| Heat saving in locomotive with heater as compared to injector operation, per cent | 15.0 | 12.75 | 13.94 | 11.80 |
| Heat required, per cent | 87.0 | 89.25 | 87.81 | 89.95 |
| Heat saving as compared to injector operation, per cent | 13.0 | 10.75 | 12.2 | 10.05 |

The tabulation given in Table 1 is based on heating the feedwater to 215 deg. This is quite conservative as it has been found easily possible to obtain this temperature with this heater even with tender-water temperatures of 40 deg. and on locomotives worked at less than two-thirds of their maximum steaming capacity. The tabulation shows that greater heat saving is possible with saturated than with superheated steam locomotives; therefore the percentage of coal saving will be greater with saturated- than with superheated-steam locomotives.

From the tabulation it will also be noted that in the case of the feedwater heater for the locomotive, because of its comparison to injector operation, it is not possible to apply the usual short rule customary in stationary practice stating that a certain number of degrees of heating of the feedwater results in 1 per cent heat saving, but rather that it is more exact to state, assuming the conditions of the table, that in the saturated steam locomotive, after the first 23.8 or 23.2 deg. heating, each 11.9 or 11.6 deg. of heating represents 1 per cent heat saving, and that in the superheated steam locomotive after the first 22.3 or 21.8 deg. of heating each 12.8 or 12.5 deg. of heating represents 1 per cent heat saving, the first figures in each case applying with 40 deg. and the second figures with 70 deg. water temperature.

European practice, as far as the author is informed, involves the use of tubular heaters differing only in details of their construction and discharging to the track the water condensed from the exhaust steam in the heater, thus losing both this water and its heat, necessarily with some additional steam that must be blown through the heater to prevent it becoming air-bound. These locomotives require 2 per cent more water than when operated with the injector because of the steam used by the feed pump and discharge to the track from 15 to 18 per cent of this with from 2.6 to 1.8 per cent of the heat of the saturated and 2.4 to 1.6 per cent of the heat of the superheated steam locomotive in the water alone for 40 and 70 deg. water respectively. There are a few surface heaters in operation on locomotives in this country in which this water is saved by pumping it back to the tender through filters to remove the oil, but in doing so approximately 80 per cent of its heat is lost by radiation from the tender. This loss of heat from the locomotive with the surface heater does not count directly against the coal saving since it is supplied by the exhaust steam, but it does count indirectly since it decreases the amount of exhaust steam left available for the draft. The open heater is more economical in the use of exhaust steam and leaves more available for the draft with the possibility of lower back pressure and saving because of this.

The locomotive with the open heater or the surface heater saving the water condensed from the exhaust steam requires the extra 2 per cent steam to operate the feed pump, but from 15 to 18 per cent of this 102 per cent is recovered, so that the net water saving is from 13.3 to 16.4 per cent respectively for the assumed summer and winter conditions as compared to injector operation.

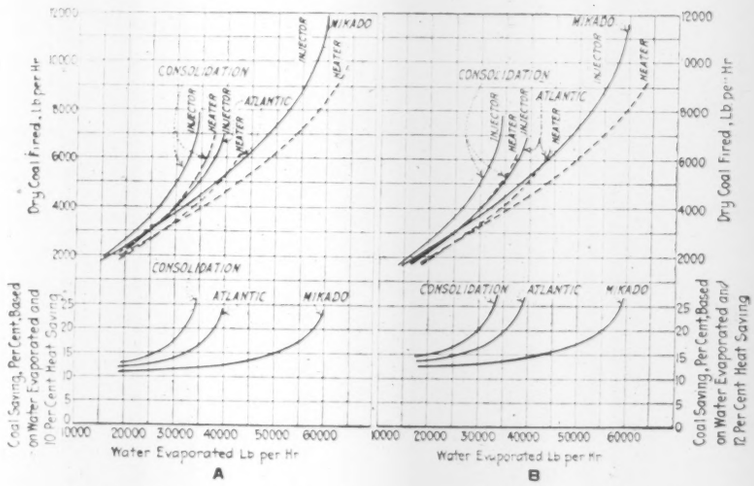
CONSOLIDATION
ATLANTIC
MIKADO
INJECTOR
HEATER
Dry Coal Fired, Lb per Hr
Coal Saving, Per Cent, Based on Water Evaporated and 10 Per Cent Heat Saving
Coal Saving, Per Cent, Based on Water Evaporated and 12 Per Cent Heat Saving
Water Evaporated Lb per Hr
A
B

FIG. 3 CURVES SHOWING THEORETICAL COAL SAVING BASED ON WATER EVAPORATION

## COAL SAVING BASED ON WATER EVAPORATED

To combine these results with the second factor in order to obtain the coal saving based on water evaporated it is necessary to consider particular locomotives since the second factor involves the change in the efficiency of the boiler with varying boiler capacity. For this purpose the curves of Fig. 3 have been prepared. The curves on the left marked A are on the basis of 10 per cent heat saving; those on the right marked B on the basis of 12 per cent heat saving. The upper solid curves marked "Injector" are test plant results of a Consolidation, Atlantic, and Mikado type locomotive respectively and show the total amount of water evaporated per hour against dry coal fired. The dotted curves marked "Heater" for each of these three locomotives show the amount of water that would have been evaporated by the same amount of coal with a feedwater heater reducing by 10 per cent and 12 per cent respectively the amount of heat required to evaporate the water and superheat the steam. The vertical distances between the solid and dotted curves represent the amount of coal saved and these quantities are shown in the lower set of curves. This lower set of curves, therefore, shows the coal saving based on water evaporated due to the feedwater heater that follows a reduction of 10 per cent and 12 per cent respectively in the amount of heat necessary to evaporate the water and superheat the steam.

It would be difficult to credit this result were it not warranted theoretically by the second factor mentioned above, and had it not been confirmed in test plant results with a wide margin to spare. A study of the upper curves in connection with the lower curves of both figures will show that the very great coal saving possible is accompanied by an increase in steaming capacity due to the feedwater heater and that it should be possible to work the locomotive with the heater at greater steaming capacities than are possible with the injector, but how much greater would depend largely on the particular locomotive.

Referring to the lower set of curves of Fig. 3 and assuming that the consolidation locomotive would be operated normally at a steaming rate of say 25,000 lb. per hr., it is noted that the 10 and 12 per cent heat savings assumed as summer and winter conditions would result in 14 and 16.6 per cent coal savings, respectively. Assuming that the Atlantic type of locomotive would also normally be operated at a steaming rate of 25,000 lb. per hr., the coal saving would be 12.8 and 14.5 per cent respectively. Assuming that the Mikado locomotive is hand-fired and operated at a steaming rate of 37,500 lb. per hr., the coal saving would be 12 and 14.2 per cent, respectively.

On the other hand, it is altogether possible that advantage should be taken of the feedwater heater either in increased speed or increased hauling capacity, and the same amount of coal burned with it as would have been burned if the locomotive had been operated with the injector. In this case, the summer-time 10 per cent heat saving would result in a $\frac{100}{100-10}$ per cent steaming capacity, or 11.1 per cent increase; and the 12 per cent heat saving would result in a $\frac{100}{100-12}$ per cent steaming capacity, or an increase of 13.6 per cent. But as compared to injector operation of the first two factors as shown in Fig. 3, leading up to the Consolidation locomotive would be 15.5 and 19 per cent, in the Atlantic locomotive 13.3 and 15.5 per cent, and in the Mikado locomotive 13 and 15.3 per cent respectively.

The feedwater heater does not appear to as great advantage in the Mikado locomotive as in the other type locomotives because

it is not as fully loaded. If the Mikado locomotive was operated at a steaming rate of say 50,000 lb. per hr., the assumed 10 and 12 per cent heat saving would have resulted in a 15 and 17.3 per cent coal saving respectively, and if advantage had been taken of the feedwater heater for the increased capacity burning the same amount of coal as with the injector, the coal saving would have been 18 and 21.2 per cent respectively.

### Coal Saving Based On Indicated Horsepower

Any modification which the third factor makes in the combination of the first two factors as shown in Fig. 3, leading up to the coal saving per indicated horsepower, must be but slight and depend on the particular locomotive. Saturated steam locomotives should show a further gain of a few per cent from reduced back pressure. Test plant records show some reduction in this back pressure in superheated steam locomotives accompanied by a reduction in superheat and indicate that, at least until further tests are made, this factor should not be considered for superheated steam locomotives.

Table 2 and the curves of Fig. 4 are test-plant results of a Mikado locomotive, comparing its operation with the injector and

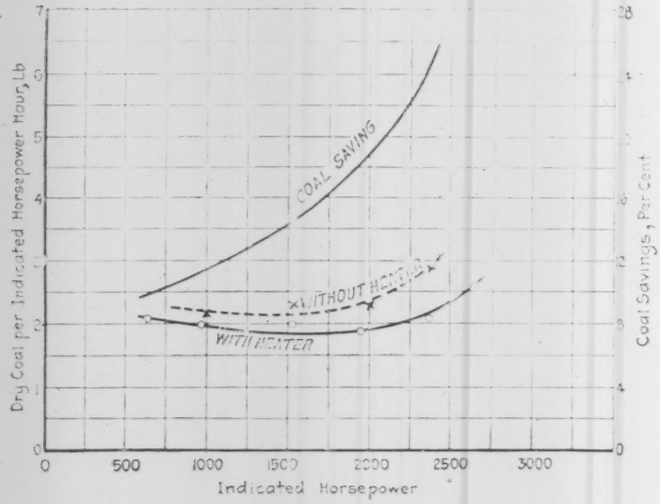


Fig. 4 Curves Showing Coal Saving Based on Indicated Horsepower

with the feedwater heater described in this paper. They show a coal-saving curve of the same general character, but slightly higher than the curve for the Mikado locomotive of Fig. 3-B, which is based on water evaporated, although the tests were made under practically identical operating conditions as to temperatures and pressures.

The coal-saving curve of Fig. 4 has been reproduced in Fig. 5, and a curve added showing the reduction in the amount of heat required to evaporate the water and superheat the steam because of the heater. The cross-hatched area below this curve shows the saving in heat due to the heater. The cross-hatched area above this curve shows the additional saving, presumably all due to the better efficiency of the boiler with the reduced amount of heat required from the fire because of the heat recovered by the heater.

### Exhaust Steam Available for the Draft

Question has been raised as to whether the exhaust steam taken from the locomotive by the feedwater heater would cause trouble with the draft. This question could be analyzed from the partly theoretical curves of Fig. 3, but as actual operating conditions are of more interest, curves have been added to Fig. 5, showing the total exhaust steam taken by the heater and the exhaust steam taken from the exhaust ports of the locomotive. The distance between these two curves represents the exhaust steam furnished by the feed pump to the heater. It is noted that the curve of exhaust steam taken from the exhaust port is below the curve of coal saving. The feedwater heater, therefore, reduced the amount of coal burned at a greater rate than it reduced the amount of exhaust steam, so that there was a surplus of exhaust steam left available for the draft, no necessity for reducing

TABLE 2 COAL SAVING AND INCREASE IN EFFICIENCY WITH FEEDWATER HEATER

| Test Nos. | 1 and 5 | 2 and 6 | 3 and 7 | 4 and 8 |
|---|---|---|---|---|
| Speed in m. p. h. | 14.6 | 14.6 | 22.0 | 22.0 |
| Indicated Horsepower | | | | |
| Without heater | 990 | 1549 | 2001 | 2388 |
| With heater | 965 | 1544 | 1949 | 2373 |
| Coal per indicated horse-power hour, lb. | | | | |
| Without heater | 2.2 | 2.3 | 2.3 | 2.9 |
| With heater | 2.0 | 2.0 | 1.9 | 2.2 |
| Coal saving by feed heating, per cent | 9.1 | 13.1 | 17.4 | 24.7 |
| Drawbar horsepower | | | | |
| Without heater | 824 | 1289 | 1690 | 2019 |
| With heater | 783 | 1293 | 1679 | 2055 |
| Thermal efficiency of locomotive, per cent | | | | |
| Without heater | 7.0 | 6.7 | 6.7 | 5.4 |
| With heater | 7.6 | 8.0 | 8.6 | 7.8 |
| Increase in efficiency with heater, per cent | 8.5 | 19.4 | 28.3 | 44.4 |

the size of the blast nozzle and consequent possibility of reduced back pressure in the locomotive cylinders because of this heater. For instance, at 2000 i.hp., the reduction in the amount of coal burned was 18 per cent, and in the amount of exhaust steam 12½ per cent. As compared to injector operation, 82 parts of coal had to be burned and 87½ parts of exhaust steam were left available for the draft to burn it.

### Conclusions

The feedwater heater on the locomotive may be used to reduce the coal and water consumption working the locomotive at the same capacity as with the injector or to increase the capacity of the locomotive, or partly for both, as occasion demands. It will

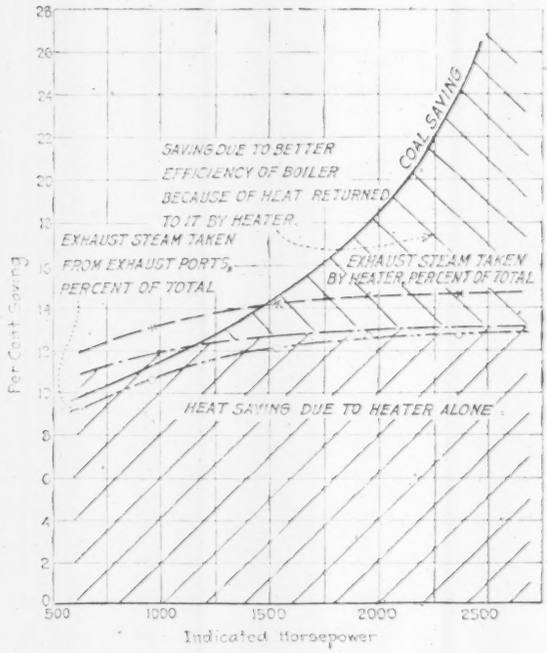


Fig. 5 Analysis of Coal Saving Based on Indicated Horsepower with Exhaust Steam Left Available for Draft

save coal and water all the time, and permit of increased capacity when needed.

The feedwater heater might be considered as alternate to large size of locomotive boiler and grate as a means to coal economy,

(Continued on page 316)

# Efficiency of Natural Gas Used in Domestic Service

## Results of Tests on Commercial Burners Under Kitchen Conditions, Showing Effect of Gas Pressure and Distance Between Burner and Vessel on the Efficiency

By ROBERT F. EARHART,[2] COLUMBUS, OHIO

*The following paper describes a series of efficiency tests on natural gas which the author made in the physics laboratory of Ohio State University. The operating conditions under which the tests were made were similar to those which commonly obtain in domestic service. Eight pounds of water were heated, in a granite-ware kettle, from the temperature of the tap to the boiling point. The definition of efficiency adopted is: heat-units employed in raising temperature of water divided by total available heat units in gas consumed. The tests show that, under low-pressure conditions, an efficiency greater than 45 per cent can be secured when the burner is close to the vessel and that an equal efficiency can be obtained with the flame up to a distance of two inches from the vessel, under high-pressure conditions. It is further shown that with reasonable care in adjusting these distances the efficiency is independent of the rate of gas consumption and that under the varying conditions which now exist, it is advisable that the distance between burner and vessel should be between 1 and 1½ in. This will render operation possible under low pressures with fair efficiency and will lie within the range of maximum efficiencies which may be secured at moderate pressures and without undue sacrifice of time. A final experiment shows that a slight increase in efficiency is obtained by using an aluminum instead of a granite-ware container.*

Of the three divisions of the natural gas industry: production, distribution and utilization, utilization now offers the most inviting field for improvement and conservation. The general topic to be studied is the relation between the thermal content and efficiency of a gas. The term "efficiency" as applied to the utilization of gas in the kitchen of the average home is a very indefinite term. Leaving out of account the operation of a furnace, the ordinary household processes are boiling, baking, frying, and perhaps ironing. In several of these it is impractical to formulate a rigorous definition of efficiency. In baking, the B.t.u. actually put into the loaves of bread should form the numerator of the efficiency fraction. The number of B.t.u. which must be expended to bring the oven to the proper temperature and the number radiated during the actual baking process cannot properly be regarded as units directed into performing useful work. The process of frying involves a similar difficulty in developing a satisfactory definition of efficiency.

The boiling process involves less difficulty. The intent, usually, is to direct a sufficient number of heat units against a vessel so that the liquid contained therein may be raised from room temperature to the boiling point. In formulating our particular definition for efficiency, only those heat units used in raising the temperature of water are regarded as performing useful work. The heat used in raising the temperature of the containing vessel is not reckoned as useful work; i. e., the water equivalent is neglected.

Among the factors which determine the efficiency of a particular gas are (1) the type of burner, (2) the pressure of the gas, (3) the size of the mixer, (4) the rate of flow of the gas, and (5) the distance from the burner to the bottom of the containing vessel. The one factor which seems to combine these is the location of the tip of the flame with reference to the containing vessel. When the tip of the flame impinges on the bottom of the vessel, the various separate factors are so determined as to yield a maximum efficiency. The deviation from this best position produces considerable variation.

### Methods and Apparatus Used in Test

In these tests, 8 lb. of water were placed in a granite-ware preserving kettle. The water was raised from the temperature at which it was drawn from the tap, to the boiling point. The vessel measured 8 in. across the bottom, weighed 2.03 lb. and was provided with a tin cover. A thermometer was suspended in the vessel, passing through a small hole located 1½ in. from the center of symmetry of the cover. The vessel was supported by an iron ring-stand touching it only at the periphery, so that there was no obstruction between the burner and the bottom of the vessel. The arrangement is shown in Fig. 1. The gas was metered through a Wright wet meter, the indicator of which made one complete revolution of the dial for 0.1 cu. ft. and could be read accurately to 0.001 cu. ft. During a test, the time of each passage of the pointer over the zero of the scale was accurately noted and recorded. The rise in temperature of the water in the vessel was noted at two-minute intervals up to within a few degrees of the boiling point and then, at one-minute intervals. These data could then be plotted and the curves extrapolated when changes in boiling point due to variation in atmospheric pressure sometimes made it desirable to compare exactly equal ranges in temperature. Plotting the gas-consumption curve and the temperature curve of the water made it possible to ascertain the exact amount of gas consumed during any given rise in temperature of the water. The meter having been accurately calibrated and the temperature and pressure of the gas observed, its volume was reduced to standard conditions, viz., 30 in. pressure at 60 deg. fahr. The rise in temperature of the 8 lb. of water being observed, the number of B.t.u. per cu. ft. of gas developed was computed, this figure serving as the numerator of the efficiency fraction. The total B.t.u. content was determined by means of a constant-flow gas calorimeter manufactured by the American Meter Company and loaned by the Ohio State Utilities Commission for these tests. The gross B.t.u. content was determined: also the net B.t.u. content, which is the gross value less

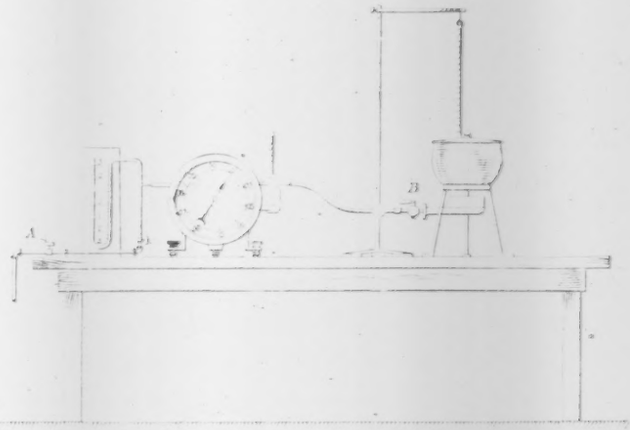


Fig. 1 Arrangement of Apparatus for Determining Efficiency of Gas

[1] This article is one of a series on the physical properties of natural gas. Former articles have appeared as follows:

Deviation of Natural Gas from Boyle's Law, R. F. Earhart and S. S. Wyer, Trans. Am.Soc.M.E., vol. 38, p. 285.

Ratio of Specific Heats and Coefficient of Viscosity, R. F. Earhart, Trans. Am.Soc.M.E., vol. 38, p. 979.

[2] Ohio State University.

Abstract of paper to be presented at the Spring Meeting, St. Louis, May 24 to 27, 1920, of The American Society of Mechanical Engineers. Advance copies of the complete paper may be obtained gratis upon application. All papers are subject to revision.

the amount of heat given up by the product of combustion in condensing. The usual procedure was to run (1) a series of two tests with the granite kettle; (2) a series of three tests with the gas calorimeter; and (3) another test with the granite vessel.

Four types of burners, shown in Fig. 2, were used for these tests. All burners were selected because of their common use in widely distributed types of stoves and no appliances nor means of adjustment not ordinarily supplied as part of the equipment were used. Burners of types A and B were of the simplest pattern. The gas issued from them as small independent bunsen flames of equal height. These simple burners where the envelop of the flame surface is flat, gave efficiencies a little higher than the other types. As has been stated, the essential feature for maximum efficiency is that the tips of the flames impinge on the bottom of the vessel and this is best accomplished when the separate jets of burning gas are of the same height.

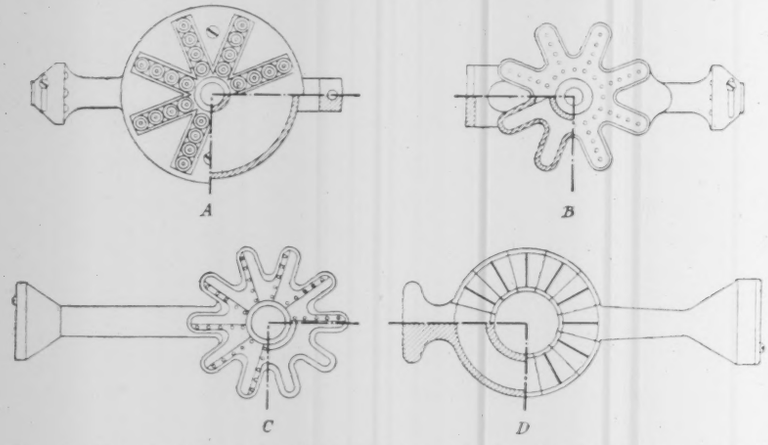


FIG. 2 TYPES OF BURNERS USED IN DETERMINING EFFICIENCY OF GAS

Twelve simple mixers which could be used on any of the burners were available. The largest of these corresponded with an opening made by a No. 28 B & S gage drill; the smallest, to a No. 60 drill. The latter is impractical for low pressures and the larger size may be used in a very wasteful manner at high pressures. In some cases a special mixing device was tried. This consisted of a mixer opening, back of which was a secondary mixer having six holes. Its only advantage is the possibility of securing a greater flow of gas under low-pressure conditions than could be obtained with the simple mixer. This advantage means flexibility of adjustment rather than efficiency.

In these tests no refined appliances were used to secure adjustments, but effort was made to utilize to the best advantage the air and gas adjustments provided as part of the regular equipment.

### EFFECT ON EFFICIENCY AT VARYING DISTANCES, PRESSURES AND GAS CONSUMPTIONS

The results secured under a variety of conditions indicate that under low pressures an efficiency greater than 45 per cent can be secured. Equal efficiencies may be obtained up to a distance of 2 in. from burner to vessel if higher pressures are used and the rate of consumption is increased. This has a practical advantage because the operation can be performed more quickly with the same efficiency. Efficiency of this order, however, could not be secured when the distance between burner and vessel exceeded 2 in.

A bulletin published in May, 1918, by Mr. S. S. Wyer and Miss Edna White, called particular attention to the fact that a maximum efficiency could be obtained with short gas flames under low-pressure conditions. Results obtained by the writer under similar conditions confirm this point. In a report of the Research Committee of the Institute of Gas Engineers of England, published in the *Gas Journal*, October 29, 1918, it is stated that efficiency is independent of gas consumption within a considerable range, provided the gas is properly aerated and proper flame contact is attained. Data upon which this conclusion is based were obtained on gas whose calorific value was about one-half that of the gas used in the present tests. The present experiments, however, are in agreement with this conclusion.

Some few measurements were made with the burner at a distance of $\frac{1}{2}$ in. from the vessel. Operating difficulty at this distance was experienced, as the flame produced was unsteady and likely to flash out, being smothered by its burned gases, and unpleasant fumes resulting. The thermal condition seemed to be good notwithstanding the bad hygienic condition. An oversupply of gas with the burner at $\frac{3}{4}$ in. gave rise to the same condition and considerable care in adjustment was required, especially when the vessel was cold.

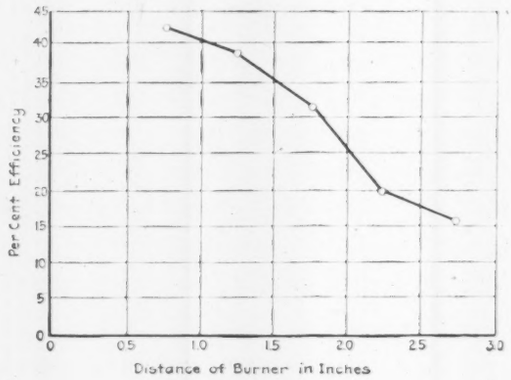


FIG. 3 EFFECT OF CHANGING BURNER DISTANCE WITH CONSTANT LOW GAS PRESSURES

### EFFECT OF LOW GAS PRESSURE

Tests were run, using the same common-size mixer throughout, to learn how low gas pressure affected efficiencies. When the pressure head falls below 0.3 in. of water, household operations are carried on with difficulty. At the start of the test, the pressure of the gas was reduced to 0.3 in. the burner set $\frac{3}{4}$ in. from the bottom of the vessel and the mixer valve adjusted for maximum efficiency. The burner was then lowered in steps of $\frac{1}{2}$ in., readings being taken at each step without additional adjustments. When the distance was increased to $2\frac{1}{4}$ in. the water could not be raised to the boiling point. Beyond a certain stage, radiation equaled input and no further rise in temperature could be obtained. At $2\frac{1}{4}$ in. the maximum temperature was 207 deg. fahr. If we regard the heat used to raise the temperature of the water to 207 deg. fahr. as usefully employed, the efficiency was 19.8 per cent. At a distance of $2\frac{3}{4}$ in. the maximum temperature attained was 197.5 deg. fahr. When we distort our definition of efficiency

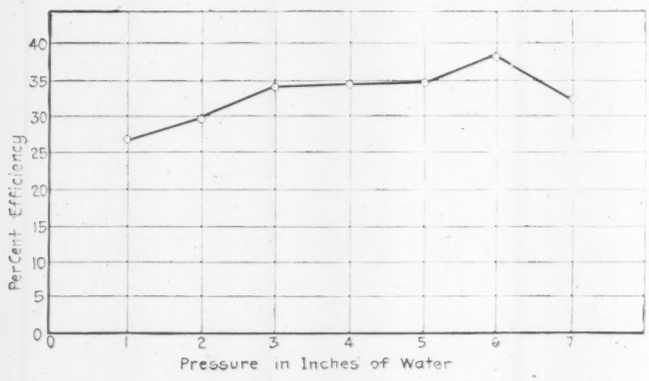


FIG. 4 EFFECT OF PRESSURE VARIATION WITH MIXER VALVE WIDE OPEN, BURNER DISTANCE CONSTANT

(*Continued on page* 316)

# ENGINEERING SURVEY

## A Review of Progress and Attainment in Mechanical Engineering and Related Fields, as Gathered from Current Technical Periodicals and Other Sources

SUBJECTS OF THIS MONTH'S ABSTRACTS


Head Resistance of Aeroplane Radiators
Aeroplane Radiators with Streamline Casings
Aerial Transport of Woolen Goods
American Competition with British Trades
Condenser Tube Corrosion
Corrosion of Brass, Five Types
Old Rails and Transverse Fissures
Aeroplane Wood, Kiln Drying
Reinforcing Bars for Concrete
Holzwarth Gas Turbine Developments
Electrolytic Iron for Gas-Turbine Blades
Balanced Hydraulic Valve
Hydraulic Recoil and Recuperator Gear Valves for Gun Carriages
Bergsund Original Surface-Ignition Type Engine
Low-Pressure Indicator Diagrams for Constant-Volume Engines
Relieving Attachment for Lathe
British Battle Cruiser "Hood"
Signaling Pyrometer
Motor Sled
Laxtonia Twin-Six Motor-Car Engine
Twin-Six Engines, Angle and "V" and Vibration
Standardization of Power Plants


## AERONAUTICS (See also Engineering Materials)

### Head Resistance of Radiator Cores—Resistance Due to Nose Radiators—Streamline Casing for Free Air Radiators

Head Resistance Due to Radiators. The present report consists of three papers, of which the first, by R. V. Kleinschmidt and S. R. Parsons, treats of the Head Resistance of Radiator Cores. The main conclusions arrived at are as follows:

The shape and size factors are insignificant for the range covered (8 by 8 in. to 16 by 16 in. and 12 by 24 in.), there being no perceptible variation in the resistance per square foot.

The effect of inclining the surface of the radiator to the air stream (yawing) is, in general, to increase the resistance considerably for angles up to at least 30 deg. to 45 deg. Cores of special construction vary greatly in this characteristic.

The horsepower absorbed by the radiator in being lifted and pushed through the air is high, being, at 100 m.p.h., roughly 5 per cent to 20 per cent or more of the total power developed by the engine. It thus appears that a small gain in radiator performance may be very appreciable at high speeds.

The investigation would indicate that a high head resistance is not in itself a detriment to a radiator if properly placed in the aeroplane. A radiator placed in the open air as between the planes or beside the fuselage must be of low head resistance. In the case of nose radiators the real limit is the frontal area which may be occupied. On the other hand, if the radiator is placed in the wings, head resistance is of little detriment.

A table giving the characteristics of various radiator cores and a table of comparisons of head resistance of radiator cores are given in the original article.

The second paper, comprising a preliminary report on Resistance Due to Nose Radiators, by R. V. Kleinschmidt, is based on wind-tunnel tests over model fuselages which show qualitatively that at any given plane speed the total resistance of a fuselage with the front nose radiator is increased by increasing the air flow through the radiator.

It would further appear that the resistance of a fuselage with streamline nose is increased more by removing the streamline nose and substituting a radiator than it is by adding an equivalent unobstructed radiator and retaining the streamline nose.

A brief report on the Effect of Streamline Casing for Free Air Radiators, by S. R. Parsons, would indicate that head resistance can be decreased very materially in this way, but the accompanying decrease in mass flow of air through the radiator and consequently in heat transfer nullifies the advantage gained, with the possible exception in the case of very high speeds. (*National Advisory Committee for Aeronautics*, Report No. 61, 1920, Preprint from the Fifth Annual Report, 22 pp., illustrations, *ep*)

Comparative Merits of Magneto and Battery Ignition System on Liberty-12 Aero Engine. Data of tests in which the Dixie magneto represented one system and the Delco the other system.

The engine was connected to an electric cradle dynamometer in the customary manner. Tests were first conducted to determine the difference in fouling of spark plugs when used with either of the two systems. To determine this the engine was run with each ignition system for one-half hour at idling speed, and then at one hour at normal speed under full throttle operation, allowing one gallon of lubricating oil to flow into the intake system during each run. To do this the center pet cock of each of the four intake manifolds was connected with the corresponding outlet from a calibrating container filled with lubricating oil, the amount of flow being regulated by means of a valve.

The results of tests appear to be as follows: When the engine was run at idling speeds, the plugs fouled equally, no matter what system of ignition was used. The difference in power output on these runs is accounted for by the fact that the run with the Delco system was made with the spark fully retarded, while the run with the Dixie system was made with the spark fully advanced. During the one-hour runs at full power none of the plugs ceased firing with either system, the oil merely burning on the plugs to form carbon. The resultant carbon deposits were about the same with either system. The power runs show that the magneto ignition gave a little more power both on the one-hour run and the run with set spark. To offset this, however, it should be noted that on the last power run with the battery ignition and spark set at each speed the power obtained was much higher than that which was obtained on any previous run, either with magneto or battery ignition. It is therefore concluded that spark-plug fouling and power output are the same for both systems, within the limits of experimental error. (*Air Service Information Circular, Engineering Division, Air Service*, McCook Field, Feb. 13, 1920, vol. 1, no. 17, 2 pp., *ee*)

Aerial Transport of Woolen Goods. Owing to the congestion of traffic at Hull Docks and to the dockers' strike at Amsterdam, the transport of goods from the Midlands to Holland, which has been taking the preposterous time of from six to eight weeks, has, for the meantime, become quite impossible. For this reason Messrs. Heatons (Leeds), Limited, who do considerable business with Holland in ladies' clothing, decided to despatch by aeroplane a quantity of goods which they were anxious to deliver in Holland in time for the spring season. A Blackburn "Kangaroo" commercial aeroplane was therefore chartered, from the North Sea Aerial and General Transport Company, of Leeds, to convey 22 packages, with an aggregate weight of over 1000 lb. to Amsterdam. The machine was loaded at Brough aerodrome, near Hull, on Friday, March 12, and proceeded to Lympne, near

Folkestone, for examination by the air-port authorities and thence to Soesterberg aerodrome at Amsterdam, where it arrived safely on the following day. The Dutch customs authorities arranged to examine the cargo immediately on its arrival, so that the packages could be despatched to their final destinations with little or no delay. The machine was expected to return with a valuable cargo of dyes of a class urgently required in Yorkshire and Lancashire. It is hardly necessary to point out that the commercial value of the service would be greatly augmented if the visit to Lympne for customs examinations could be avoided. Lympne is, at present, the only recognized point of departure for Continental aerial traffic, and this fact is obviously a severe handicap on aircraft traveling from the northern counties to Holland and the Baltic. Evidently the traffic would be greatly facilitated by Government recognition of an air station on the North Sea coast, since a direct flight across the North Sea could be made in half the flying time, and in much less than half the total time, owing to the fact that the long southward diversion renders a night's stay at Lympne unavoidable. (*Engineering*, vol. 109, no. 2828, March 12, 1920, p. 344, *g*).

## CORROSION (See Engineering Materials)

## ECONOMICS

AMERICAN COMPETITION WITH BRITISH TRADES. This subject is discussed in *The Engineer* (London) in an editorial entitled The Question of American Competition.

The writer calls attention to the sales efforts of American concerns in Europe; such as the fact that a leading American locomotive firm is alleged to have sent a representative to The Hague where he offered to quote prices not only on locomotives and other railroad equipment but also on all kinds of machinery, including machinery for treating sugar, rubber, coffee and cocoanuts in tropical countries.

On the other hand, it is stated that in the calendar year of 1919 American exports decreased while imports increased, the reduction being due to the fall in the quantity of semi-finished steel sent out of the country for the account of the Allied nations. The imports increased through purchases of scrap and pig iron. (The statistics refer, of course, exclusively to the metal and machinery trades.)

If the American statistics are contrasted with those for Great Britain, it is found that the British exports showed a recovery for the first year after the end of active hostilities. The exports rose from 1,618,000 tons in 1918 to 2,254,000 tons in 1919, being an advance of 636,000 tons, giving a net balance of 360,000 tons to the advantage of Great Britain. The figures in the case of machinery are also hopeful for Britain, although a strict comparison between the latter and the United States cannot be made. The British exports advanced in tonnage by 65 per cent as compared with the preceding year.

As regards the future, it is stated that American steel and machinery makers have secured a great hold on international markets under the abnormal circumstances of a world-wide war, and thereby have become enormously enriched. Furthermore, though peace prevails, the conditions throughout the world have not become normal and probably will not do so before several years have elapsed. There is a great international demand for iron, steel and different classes of machinery in various countries and it is believed that Great Britain will obtain its fair share of this world trade as in former years. In fact, figures appear to show that it has already been able to make a fresh and favorable start in the resumption of its former position in the markets of the world. Though the present high prices tend to facilitate American competition in external markets, except where the rate of exchange exercises an unfavorable influence upon prospective customers, nevertheless the amount of work available in the world is so enormous that international competition for the purpose of securing it should be inconsiderable for a long time to come. (*The Engineer*, vol. 129, no. 3349, Mar. 5, 1920, pp. 249-250, *g*)

## ENGINEERING MATERIALS

### Classification of Types of Corrosion of Brass

THE CORROSION OF CONDENSER TUBES. Abstract of the Fifth Report of the Corrosion Committee of the Institute of Metals, confined to the corrosion of condenser tubes, mainly 70:30 brass.

The first section deals with what has been called the diagnosis of condenser-tube corrosion and describes the procedure to be followed in withdrawing and preparing a tube for examination, and also symptoms indicating corrosion. Conditions existing within the plant, in particular, water supply, are stated to be of great importance.

The second section is devoted to a consideration of certain features in the structure of condenser tubes and attention is directed to the presence on the tubes of a surface layer consisting of structureless, highly distorted metal. This layer has a greater resistance to corrosion than the underlying crystalline metal so that whenever this layer is penetrated corrosion will proceed at an increased rate. The thickness of this layer is usually of the order of 0.01 mm. (0.00039 in.) and indications have been obtained that its composition may be different from that of the underlying metal.

In the third section the five main types of brass-condenser-tube corrosion are considered in detail. These types are:

*Type I, General Thinning.* This may be considered as an accelerated form of the complete corrosion which normally occurs in saline solutions, the tube being gradually and uniformly reduced in thickness. Rapid general thinning, however, is essentially a fresh-water phenomenon and is usually associated with the presence of free acid in the water supply. Tests have shown that even with dilute solutions of hydrochloric acid such as 3 parts in 100,000, in six weeks tubes had lost from 3 to 4 per cent in thickness. Proper neutralization of the acid is an effective remedy for this trouble. It is difficult, however, to detect the acid, especially if it appears in the water supply only intermittently.

*Type II, Deposit Attack.* This results in pitting and is based on the following chemical reaction. In the presence of sodium-chloride solution the cuprous oxide formed on a brass surface gradually changes to cuprous chloride. This latter is usually swept out of a condenser tube by the circulating water, but under various conditions may adhere at different parts of the tube surface. When such adherence has occurred, conditions allow of the further gradual change of the insoluble cuprous chloride under the influence of oxygen to soluble cuprous chloride and cuprous oxide. The action of cupric chloride solution on brass is very rapid and, for example, a piece of brass tube 2 in. long, placed in a strong cupric chloride solution at ordinary temperature, was completely disintegrated and partially replaced by a pseudomorph in copper in two days.

*Type III, Dezincification.* In dezincification, in the case of a 70:30 brass, true parting of zinc and copper does not occur but the so-called residual copper is always redeposited copper. There is therefore no real but only apparent dezincification. The layer type which is characterized by the disintegration of the brass tube and redeposition of copper over large areas has been found to occur with both salt and fresh water, and several ways in which it may occur are indicated.

*Type IV, Plug or Local Dezincification.* This type of corrosion always proceeds beneath a deposit and is stimulated by the presence of foreign bodies. It differs, however, in many ways from Type II. So far as is known, it occurs only in sea water and is always associated with appearing quite salt consisting of colloidal zinc oxychloride, also containing some carbonate. The dezincifying action is thought to be due to a small concentration of hydrochloric acid contained within the colloidal white salt. The behavior of different tubes is not always the same and the reason for it is not clear.

*Type V, Waterline Attack.* In brass tubes only partially immersed in sea water increased corrosion takes place not at the waterline itself but above it—sometimes as high as 2 cm. (say,

0.8 in.) above the air-sea-water surface. Further, the attack is not uniform but is concentrated at areas where salt deposits have formed. This type of attack may occur at the inlet end of the tube and is prevented by eddying effects from being swept away by the water flow.

The fourth section of the report contains an account of preliminary work on the electrolytic protection of condenser tubes. The particular question investigated was that of the efficiency of electrolytic protection in preventing deposit attack. It is considered that a small electric current slows down, but does not necessarily inhibit corrosion. By raising the current density sufficiently it is possible to prevent all corrosion, even in a cupric chloride solution, but the current must be quite heavy. (Official Abstract of the Fifth Report on Corrosion to the Corrosion Committee of the Institute of Metals, *ep*. *The Engineer*, vol. 129, no. 3350, Mar. 12, 1920, pp. 267-268, *e*.)

## No Fissures in Old Rails

OLD RAILS. A report by W. C. Cushing, Chief Engineer of Maintenance, Pennsylvania Lines West of Pittsburgh, gives an interesting sidelight on the cause of the appearance of transverse fissures.

This report covers an investigation of rails which had been in service from 10 to 45 years; some of the oldest were of wrought iron, others rolled from iron and steel pile, while others 10 to 25 years old were of bessemer steel.

In the old wrought-iron rails, head strains corresponding to 24,000 to 27,000 lb. per sq. in. in compression were found, which appeared the more serious because the material had a low elastic limit, 26,670 to 48,760 lb. per sq. in. The piled rails showed maximum head strains of 24,000 lb. per sq. in., and the elastic limit of the material ranged from 33,700 to 58,830 lb. per sq. in. Still higher internal strains, however, were found in steel rails that had been in service 20 to 25 years, several measurements of 36,000 to 33,000 lb. per sq. in. being made, as against elastic limits of 46,500 to 58,450 lb. per sq. in. These high values of permanent strain were measured at the surface of the head and on the side opposite the gage side in nearly every case. One abnormal result was a reading of 57,000 lb. per sq. in., tensile stress, in the flange of an 85-lb. rail that had been in service nearly 20 years (from 1898 to 1917); Mr. Cushing calls this "extraordinary and inexplicable."

From a knowledge of the service to which these rails were submitted, one would expect to find them filled with transverse fissures. In fact, rails adjacent to them and undergoing precisely the same condition of service had been found to contain such fissures, which would indicate that the difference in the behavior of the two classes of rails must be sought in the process of manufacture. (Report No. 84 to the Rail Committee of the American Railway Engineering Association, abstracted through *Engineering News-Record*, vol. 84, no. 11, March 11, 1920, p. 527, *g*.)

THE EFFECT OF KILN DRYING ON THE STRENGTH OF AEROPLANE WOODS, T. R. C. Wilson. This paper is one of a series of monographs contributed by the Forest Products Laboratory, maintained at Madison, Wis., by the Forest Service, U. S. Department of Agriculture, in cooperation with the University of Wisconsin.

It embodies the data of a series of tests which included 26 species of wood, approximately 100 kiln runs and over 100,000 mechanical tests.

These tests were made the basis of the specification (Signal Corps No. 20500) for the general kiln-drying process for aeroplane stock (now with some slight modification specification 20500-A of the Bureau of Aircraft Production).

The general conclusions of the tests reached are:

1 That wood may have its strength properties, particularly toughness or resistance to shock, quite seriously damaged without any *visible* evidence of such damage. Hence, *appearance* of the material cannot, where maximum strength is essential, be accepted as the sole basis of judgment of the effect of a drying process on wood.

2 That the effect of a given process is not the same on all species of wood.

3 That apparently a given process may be entirely safe for some but quite detrimental to other material of a species.

4 That proper kiln drying produces material equal in all strength properties to that resulting from air drying under the most favorable conditions.

5 That specification 20500-A of the Bureau of Aircraft Production (Table 1 or 2 as specified) can in most cases be expected to produce material fully equal to air-dried.

6 That best results (with respect to strength properties) on Douglas fir will result from the use of somewhat milder drying conditions than those laid down in Specification 20500-A (Table 1). Table 2 of this specification (temperatures 105 deg. fahr. initial to 135 deg. fahr. final and relative humidities 85 per cent initial to 40 per cent final) is recommended for drying Douglas fir.

7 That in some species there is apparently no relation between drying temperatures up to 180 deg. fahr. and the strength properties of the dry material. Such a conclusion, however, needs further confirmation, and temperatures higher than those of Specification 20500-A have not been recommended.

This work has been done under the necessity of getting results as quickly as possible and with the primary object of checking the safety of the general kiln-drying specifications when applied to the drying of airplane lumber on a commercial scale, together with the more or less incidental object of ascertaining if conditions adapted to more rapid drying could be used. Under these circumstances it has not been possible to investigate the subject in the fundamental way which it merits. Completion of the work already begun is contemplated and it is hoped to be able later to carry out experiments to determine the effect of the various factors involved, both separately and in combination, and to ascertain the maximum temperature and minimum humidity that can be safely applied at any stage of the drying process. It is hoped also to carry on comprehensive investigations of the closely related subject of the bending of wood, for the purpose of determining the steaming or other processes best adapted to successful bending and to secure more accurate knowledge of the effect of such processes on the strength of the wood.

An interesting part of the table is the discussion of kiln drying as it affects the various species of woods. The methods used in the tests and the kilns are illustrated in the original article. (*National Advisory Committee for Aeronautics*, Report No. 68, 1920, preprint from the Fifth Annual Report, 69 pp., 22 figs. and 9 plates, *ep*.)

REINFORCING BARS FOR CONCRETE. Discussion at the annual convention of the American Railway Engineering Association at Chicago in March, 1920.

Specific prohibition of twisted bars for the reinforcement of concrete, as provided in the masonry committee's specifications, met with some objection. Hot-twisted bars are dangerous, according to T. L. Condron, while Mr. Condron and Prof. A. N. Talbot (Mem.Am.Soc.M.E.) agreed that cold-twisted bars give no advantage over plain or deformed bars commensurate with the extra cost of the twisted bar. A suggestion that the twisting is in itself a test of the good quality of the steel was characterized by Mr. Condron as "salesman's talk." A proposal to limit the prohibition of hot-twisted bars was voted down.

Copper-plated bars, copper-alloy bars and a rough enamel coating for bars were suggested by the committee on electricity for use in reinforcing concrete subject to electrolytic action. This was accepted as information without discussion. It was pointed out that in reinforced-concrete ships protection has been based upon density and richness of concrete, and high quality of materials and workmanship, while experiments have been made with non-metallic waterproofing paints. (Abstracted through *Engineering News-Record*, vol. 84, no. 13, March 25, 1920, p. 615, *g*.)

## GAS TURBINES

### Holzwarth Gas Turbine, Thyssen Type; Large Compression and Power Output, Nozzle Design, Blade Design, Electrolytic Iron for Blades; Steam-Turbine Practice Applied to Gas-Turbine Design

DEVELOPMENT OF THE HOLZWARTH GAS TURBINE SINCE 1914, Hans Holzwarth. In 1914, a few months before the beginning of the war, tests were started on a 1000-hp. vertical gas turbine built by the firm of Thyssen & Co., in Mülheim (Ruhr). These

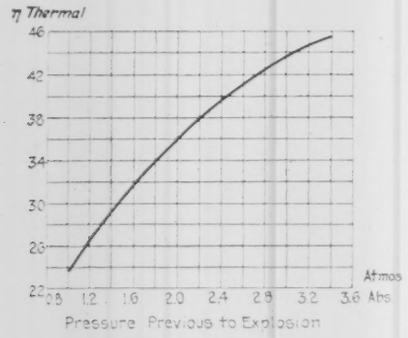


FIG. 1 THERMAL EFFICIENCY OF THE HOLZWARTH GAS TURBINE (ASSUMED TO BE FREE FROM LOSSES) AS A FUNCTION OF THE CHARGE PRESSURE PREVIOUS TO THE EXPLOSION (PRODUCER-GAS FUEL OF HEAT VALUE 500 KG-CAL. PER CU. M.; TEMPERATURE OF MIXTURE, 77 DEG. CENT.

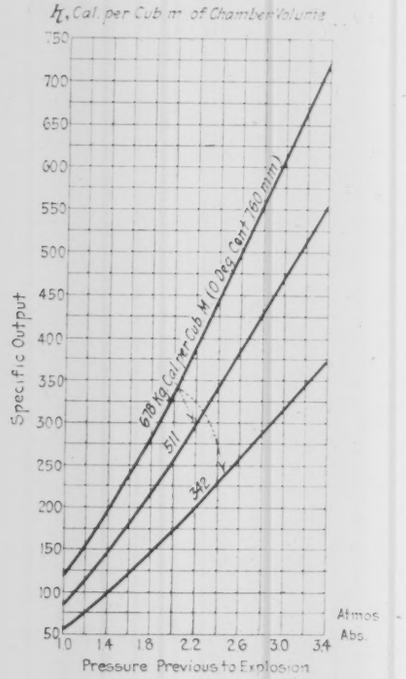


FIG. 2 SPECIFIC OUTPUT OF THE HOLZWARTH GAS TURBINE (ASSUMED TO BE FREE FROM LOSSES) AS A FUNCTION OF THE CHARGE PRESSURE PREVIOUS TO THE EXPLOSION FOR VARIOUS HEAT VALUES OF THE MIXTURE

tests were discontinued during the war, but were started over again in 1918. The Thyssen turbine does not differ in external appearance from the gas turbine previously built by the author at Mannheim, but differs from it in several particulars of design.

*Higher Charge and Explosion Pressures.* These were adopted to increase the output per cubic unit of chamber capacity and the thermal efficiency. The average explosion pressure for continuous operation was raised to from 12 to 14 atmos. abs. as compared with 5 to 6 atmos. abs. of the Mannheim turbine.

There is fundamentally nothing in the way of raising this pressure still higher by increasing the charge pressure above 2.3 atmos. abs. The curves of Figs. 1 and 2 show the influence of the charge pressure and explosion pressure on the efficiency and specific output of the turbine.

*Reduction of the Period of Expansion.* The shorter the time taken by expansion the less the loss of heat to the chamber and nozzle walls, and the greater the amount of heat transformed into kinetic energy, and hence the greater the efficiency. At present the duration of the period of expansion in the gas turbine is around 0.1 sec. In large gas engines running at 90 r.p.m. the expansion lasts about 0.33 sec., while in aircraft engines, in which the heat consumption is not materially inferior to that in Diesel engines, it is 0.02 sec. at 1500 r.p.m. Fundamentally there is nothing to prevent reducing the expansion period in the gas turbine still more. To do this, however, the nozzle cross-section must be increased, and this in turn leads to an increase in the length of the turbine blades and in flow resistances.

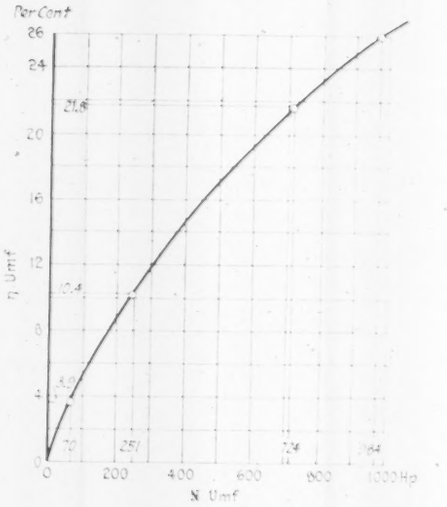


FIG. 3 TOTAL EFFICIENCY (AS MEASURED ON THE WHEEL PERIPHERY) AS A FUNCTION OF THE POWER OUTPUT AT THE WHEEL IN THE HOLZWARTH GAS TURBINE

*Changes in the Shape of Blades and Blade Fastenings.* Decrease in the period of expansion provides an increase in pressure on the blades. Furthermore, unlike what takes place in steam turbines, the jet in explosion turbines acts intermittently for short periods, and is of the character of a blow. Because of this the blade shapes and fastenings used, for example, in Curtis turbines would not be satisfactory. New blades, therefore, had to be developed which were planned to withstand the added stresses much better.

As regards the material of the blades, many kinds of alloyed and unalloyed hard and soft steels were tested, with rather unsatisfactory results, and finally a soft electrolytic iron was adopted. With proper heat treatment blades of this iron proved to be very satisfactory for use in gas turbines. Table 1 shows the physical properties of this material from tests made in the testing laboratory of the Technical High School at Stuttgart.

While blades made out of harder or alloyed steels rapidly show changes in the structure of the metal, cracks and fissures, electrolytic iron in gas-turbine blades appears to be quite capable of withstanding wear and also resistant against surface corrosion and erosion, provided, however, no substantial amounts of wet steam or water are present in the gases of combustion.

*Nozzle Shapes.* DeLaval nozzles and nozzles with parallel exit walls were tested as well as several other shapes. The advantage of nozzles with parallel walls, which lies in their offering a greater

cross-section of exit, is counterbalanced by an increase in the deflection of the jet, and on the whole it was found that steam-turbine experience applies within reason to the design of gas turbines. The most satisfactory results were obtained with DeLaval nozzles with minimum possible angle of exit, just as in steam-turbine practice.

Practical experience has confirmed theoretical expectations to the effect that the reduction of heat gradient during the expansion does not materially affect the efficiency of the gas-turbine nozzles and blading. For example, if the instantaneous maximum jet velocity at the beginning of expansion is in the neighborhood of 1500 m. per sec., more than 95 per cent of the mechanical energy of the gases of combustion is available at the wheel up to the time when the jet velocity decreases to about 1000 m. per sec. This

TABLE 1 PHYSICAL PROPERTIES OF ELECTROLYTIC IRON USED FOR GAS-TURBINE BLADES

| | | Tested at | |
|---|---|---|---|
| | | Room temperature | 450 deg. cent. |
| Yield Point | kg. per sq. cm. | 4204<br>3185 | 2675 |
| Breaking Load | kg. per sq. cm. | 4510 | 2975 |
| Elongation | Per cent | 27.2 | 30.2 |
| Contraction | Per cent | 73 | 88.4 |

means that more than 95 per cent of the energy is available at jet velocities varying 19 per cent either way from the average jet velocity for which the nozzle and blading have been designed. Practical experience confirms these theoretical considerations. Time after time useful efficiencies of about 55 per cent (i. e.,

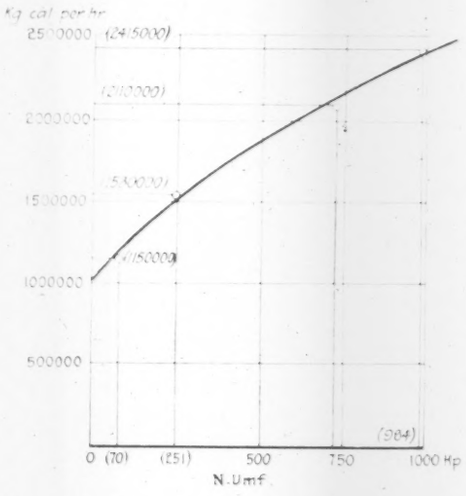


FIG. 4 TOTAL HEAT SUPPLIED AS A FUNCTION OF THE POWER OUTPUT AT THE WHEEL OF THE HOLZWARTH GAS TURBINE

about 55 per cent of the output attainable in a gas turbine free from all losses) have been indicated on the periphery of the wheel.

In steam-turbine practice the upper and lower limits in the heat-drop process are determined on one hand by the initial pressure and temperature of the steam, and on the other hand by the vacuum in the condenser. Furthermore, the peripheral velocity of the rotor is also predetermined, and all that the designer can do is to rearrange the stages in one way or another. In gas turbines the lower limit of the heat drop is predetermined and for practical purposes so are the peripheral velocity and number of stages. On the other hand, however, the designer is free to vary the upper limit of the heat drop, and through this the important ratio $\frac{\text{jet velocity}}{\text{peripheral velocity}}$ without materially affecting thereby the thermal efficiency of the turbine.

*Change in Nozzle Valves.* The employment of higher charge pressures and the increase in the cross-section of the nozzles required some changes in the design of the nozzle valves, which are described in a very general manner.

*Tests.* The tests were carried out in the presence of various railroad officials in December 1919. The fuel used was coke-oven gas with a heat content of 3860 kg-cal. per cu. m. (432 B.t.u. per cu. ft.). The turbine was driving a dynamo delivering current to a water rheostat. The main test lasted four hours and gave the results shown in Table 2.

TABLE 2 DATA OF TESTS OF HOLZWARTH-THYSSEN GAS TURBINE

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Gas consumption, reduced to 0 deg. cent., and 760 mm. mercury pressure, cbm. per hour | 300 | 400 | 550 | 630 |
| Heat supplied, cal. per hour | 1,150,000 | 1,530,000 | 2,110,000 | 2,415,000 |
| Power output at wheel $N_{umf}$, hp. | 70 | 251 | 724 | 984 |
| Heat consumption, kg-cal. per hp.-hour | 16,430 | 6,090 | 2,915 | 2,450 |
| Efficiency $\eta_{umf}$ per cent | 3.9 | 10.4 | 21.8 | 26 |

Figs. 3 and 4 give the amounts of heat delivered to the turbine per hour, and the efficiency $\eta_{umf}$ refers to the power output $N_{umf}$ delivered by the wheel. The work consumed in compressing the blast air and gas amounted to about 5.7 per cent of the exhaust heat. If the efficiency of the compressor be assumed to be 70 per cent, of the condenser steam turbine 18 per cent and utilization of exhaust heat 60 per cent, then the total efficiency for the exhaust-heat plant and the blower system is $0.70 \times 0.18 \times 0.60 = 7.6$ per cent, in which case the power consumption for the blowers can be well taken care of by exhaust heat.

*Construction.* Gas turbines of the horizontal type appear to be preferable in several important ways to vertical turbines, and it

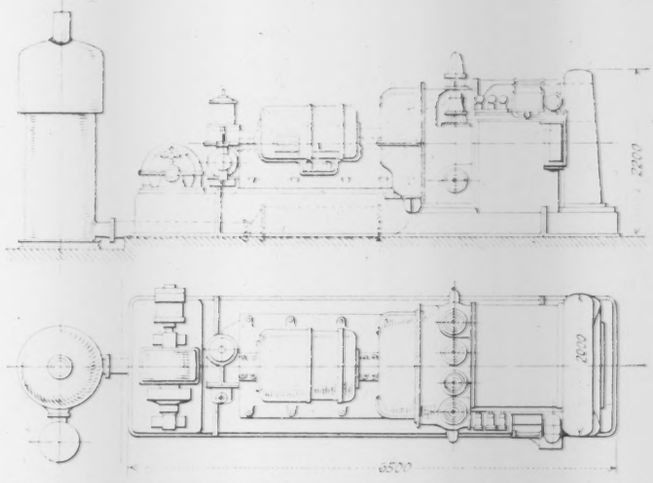


FIG. 5 HOLZWARTH OIL-FUEL GAS TURBINE, 500 HP. AT 3000 R. P. M.

is intended in the future to build only horizontal gas turbines. Fig. 5 shows the general outlines of a 500-hp. oil-fuel gas turbine now under construction to run at 3000 r.p.m. and drive a direct-current generator. The blower and exciter are built in on the same base as the main engine, and directly connected thereto is the exhaust-fuel-heated boiler delivering steam for the blowers. This installation is to go to the Prussian Railway Administration. The same article gives an illustration of a 12,000-kw. gas turbine, which seems, however, to be as yet only in the design stage.

It may be added that during the war there were several rumors of a gas turbine of extremely high efficiency having been developed by the Augsburg-Nuremberg Machine Company. In fact, it was stated that such a turbine was to be applied to drive an aeroplane. Thus far no information has become available to confirm the truth of these rumors. (*Zeitschrift des Vereines deutscher Ingenieure*, vol. 64, no. 9, Feb. 28, 1920, pp. 197-201, 14 figs., *d*.)

## HYDRAULIC MACHINERY

### Balanced Hydraulic Valve for Hydraulic Recoil and Recuperator Gears for Gun Carriages—Hydraulic-Valve Construction for Minimum Leakage

BALANCED HYDRAULIC VALVE. As a result of experience during the recent war in connection with hydraulic recoil and the recuperator gear for gun carriages, in which construction and design finally reached a stage when hydraulic pressure could be maintained in a group of cylinders for several weeks at a stretch with a loss of less than 5 lb. pressure. Mr. Pearson of the Erith Works, Vickers, Ltd., has designed the hydraulic valve illustrated in Fig. 6.

The chief points about this valve are that it has been designed to eliminate leakage at the moving parts, and that it is balanced both at the inlet and exhaust ends. Ease of effecting inspections or renewals has been also a main consideration.

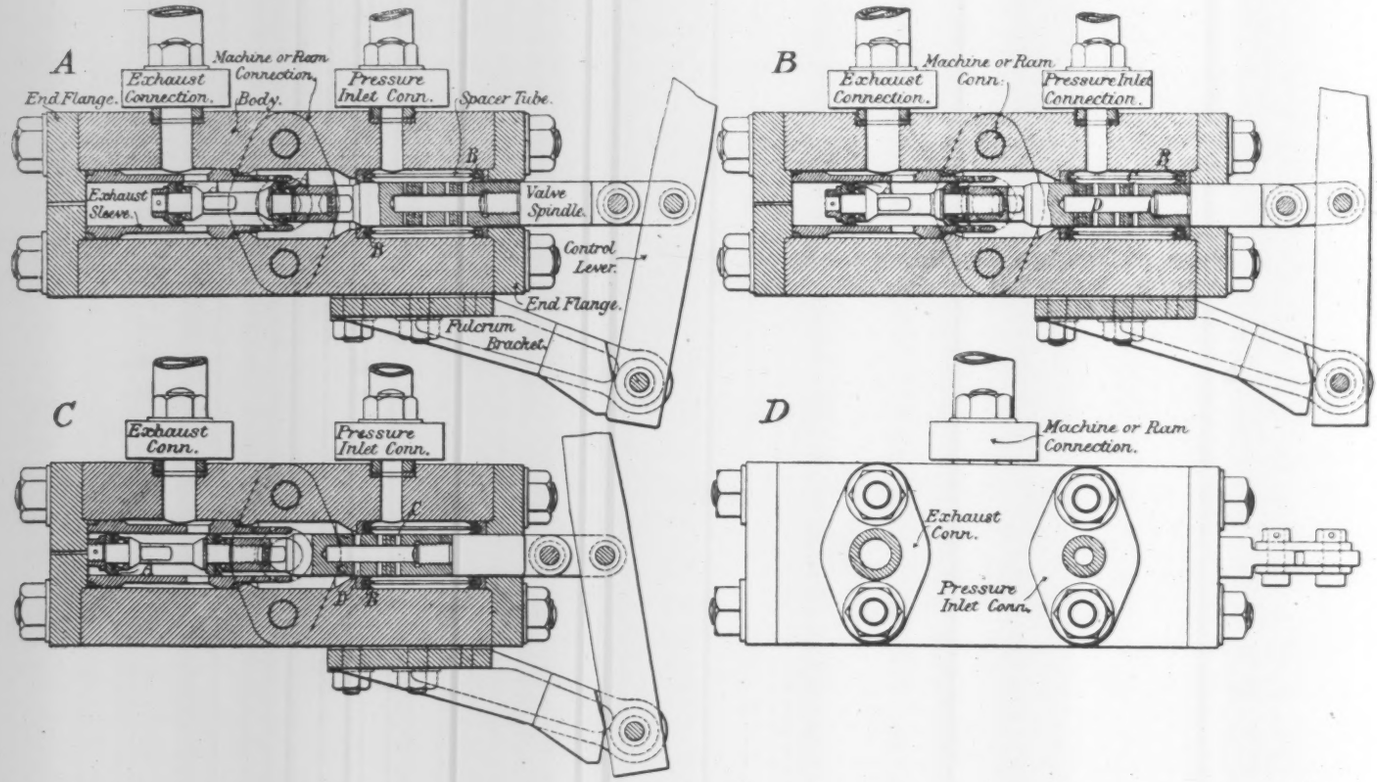


FIG. 6. BALANCED HYDRAULIC VALVE NOTABLE FOR ITS VERY SMALL LEAKAGE

The body of the valve is cut from a rectangular block of steel and bored out to take valve bushes; inside these bushes works the valve itself. In Fig. 6-A the valve is shown with the connection from the machine in communication with the exhaust. In Fig. 6-B the position of the valve cuts off the machine both from the pressure inlet and exhaust, maintaining therefore pressure on the machine and keeping it stationary. In Fig. 6-C the valve is shown putting the machine connection in communication with the pressure inlet. It will be noticed that the inlet valve is tubular, and constructed with two series of ports *C* and *D* (Fig. 6-B and C). The pressure inlet connects with the space surrounding this valve, and when in the position shown in Fig. 6-C the pressure supply is put through to the machine by way of these ports, the set *C* acting as inlets and *D* as outlets to the machine connection. At the exhaust end the ports are in the bushing, and not the valve. In the position, Fig. 6-C, with the supply and machine coupled up, the exhaust-valve head is beyond the exhaust ports in the bush, and the exhaust is cut off. In Fig. 6-A, showing the machine in connection with the exhaust, the valve head is near the open end of the bush, and the ports of the latter are uncovered, allowing connection via the interior of the sleeve, to the exhaust pipe. In Fig. 6-B, both connections from the inlet and to the exhaust are blocked. The pressure valve works in a chamber fitted with hydraulic rubber cup packings held apart by a bulb-headed spacing tube of frame, the sides of which are cut away. The exhaust sleeve is held in place and packed also with hydraulic rubber. The exhaust-valve heads are fitted with rubber packings pressed down on to the bulb-headed rings. The rubbers used in this valve are of a special composition, which thoroughly proved its great durability and efficiency in connection with gun carriages throughout the war. They are far superior to the ordinary leathers used in connection with hydraulic installations. The pressure packings and frame, and the exhaust sleeve and packings are held in place by their respective covers, which are fastened to the body by four studs and nuts. It will thus be seen that all parts may be quickly removed for cleaning and inspection; in fact, this can be accomplished and the parts replaced in less than 5 min., or in about 10 min. if new rubbers are required. The pipe connections can be bored and fitted to different sides as convenient and two or more valves can be coupled for combination working. It will be noticed that the ring packings are arranged so as to be more effective in preventing leakage. A small hole is drilled through the exhaust-end cover so that the double-headed piston exhaust valve shall be in equilibrium. The control lever can be easily moved by hand, and as the valve is balanced in all positions, will remain in whatever position it is placed.

In addition to the illustrations reproduced in this abstract the article gives two halftones, one showing a general view of the valve and the other a view with the control lever dismantled and also showing the interior components and links for the lever. The whole is an interesting illustration of a minor mechanical detail developed to a very high stage of perfection under the stress of war demands. (*Engineering*, vol. 109, no. 2826, Feb. 27, 1920, pp. 281-282, *d*)

## IGNITION (See Aeronautics)

## INTERNAL-COMBUSTION ENGINES (See also Aeronautics, Gas Turbines, Motor-Car Engineering)

BERGSUND ORIGINAL SURFACE-IGNITION-TYPE ENGINE. Description of an engine now built in Sweden but which, it is stated, is likely to be introduced soon into the American market. Its design does not essentially differ from that of similar engines now known.

Fig. 7 shows a section. The cycle is as follows: Fuel-oil is injected by the pump into the hot-bulb "*T*" via the injection nozzle *H* immediately before the piston reaches top center, and is sprayed on to the surface of the projecting surface *V*, which is heated when starting by transmission of heat from the double-lipped disk *I*, which is made red-hot by the blow lamp *B*. After the engine has been running a short time, the blow lamp is extinguished and the projection *R* and the ignition plate are kept hot by the temperature of combustion. It will be noticed that both the hot bulb and cylinder head are watercooled.

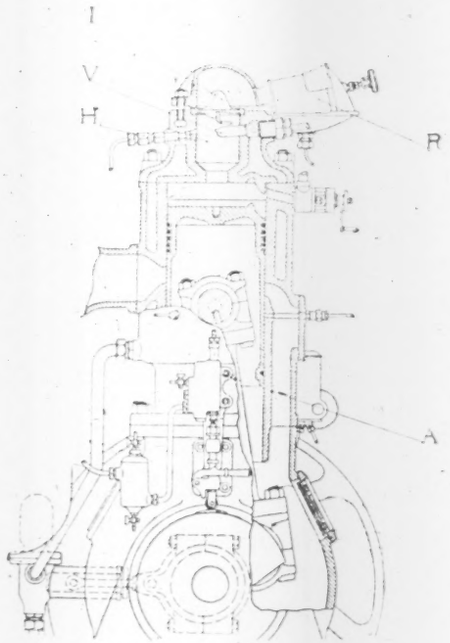


FIG. 7 BERGSUND ORIGINAL SURFACE-IGNITION-TYPE ENGINE

The projecting piece *V* has a double duty as the fuel is sprayed on it at an acute angle in an almost solid stream, and is split by it into fine particles. And, in order to avoid chance of misfire at light loads, the lipped ignition disk $V_1$, termed the light-load ignition surface, is fitted just above it, and this enables the engine to run for long periods without load, or without the use of the blow-torch.

Fuel is fed to the injector by the pump *A* which is actuated by a cam on the governor. The governor regulates the position of the cam in such a manner that the stroke of the pump is suited to the load of the engine, hence the quantity of the fuel being varied. Before entering the cylinder, the fuel oil is passed through to separate filters, one of which may be taken out and cleansed while the engine is working. All troubles from the choking-up of the fuel-oil valves and the nozzle are obviated by this arrangement. (*Motorship*, vol. 5, no. 4, April, 1920, pp. 324-326, 13 figs., *d*)

CALCULATION OF LOW-PRESSURE INDICATOR DIAGRAMS, E. C. Kemble. The investigation deals with the theoretical study of the pressure variations in an internal-combustion engine cylinder during the low-pressure part of the cycle.

The method of calculation is based on certain assumptions which are all to be regarded as rough approximations to the truth, such that it is believed that their adoption does not introduce any material errors.

In order to apply the method, it is necessary that pressures in the intake and exhaust manifolds at points adjacent to the valves and the effective clear valve openings shall be known functions of the time. By the effective clear opening of a valve is meant the product of the minimum sectional area of the passage through the valve and the coefficient of efflux.

The use of the method is of course restricted by the above requirements, since the manifold pressures are usually not known, but to a certain extent the actual varying pressure may be replaced by its average value which will give results that are interesting though not strictly correct quantitatively.

The subject of the value of the coefficients of efflux is discussed in considerable detail, the author being inclined to the opinion that the coefficients for steady flow should not differ very greatly from those applicable to intermittent flow obtained in practice, provided that the pressure used in making the calculations are those actually existing at points close to the valves.

Differential equations for the rate of change of the pressure in the cylinder during the exhaust and suction strokes are set up and a method for the graphic integration of these equations is indicated. Efflux coefficients taken from experimental data are used in the application of the theory to a typical motor and a theoretical low-pressure indicator diagram for this motor is obtained.

It is also stated that a method of computing theoretical low-spring diagrams has been developed which is capable of further development and refinements not justified by the experimental data now available. At present the absolute values deduced from the theory cannot be relied on, but future experiments may show how to modify the theory so that it will give quantitatively correct values. (*National Committee for Aeronautics*, Report No. 50, Preprint from the Fifth Annual Report, 13 pp., 7 figs., *tA*)

## MACHINE TOOLS

### Attachment Converting Ordinary Lathe into Relieving Lathe

RELIEVING ATTACHMENT FOR LATHES. It is usually considered to be uneconomical to make milling cutters and other small tools in a general engineering shop, but occasions arise when it is desirable to do so.

All the equipment necessary to make such tools is usually available in shops, but difficulty arises in connection with the work of backing off or relieving the teeth of the cutters. The teeth can, of course, be formed by milling with special cutters, but the ordinary shop cannot have all the cutters required for different shapes and sizes of tools. A relieving lathe which might be employed is likewise an expensive tool of very little general utility and it would not pay to have one to take care of an occasional odd job.

From this point of view the attachment described here and built by Milton, Ltd., London, is of interest. It is intended to take care of just the kind of job that can usually be done only on a relieving lathe or by means of special tools.

Drawings, Fig. 8, *A* to *E*, illustrate the construction of the attachment. It is mounted on a gibbed plate which is screwed on to a lathe saddle. Into this plate is fitted a steel casting having a hole through which the work passes, or the arbor on which the work is mounted between the centers of the lathe. There are also two oscillating tool posts carrying tools which can operate simultaneously on the front and back of the work, though for relieving the front tool only is employed. Provision is made for adjusting the tools in a vertical direction to allow for any alteration in height which may have been introduced by grinding, likewise for the transverse adjustment of the tools. The tools themselves fit in slots in the tool posts and are each clamped in position by a bolt and nut.

The tool posts are rocked by means of two eccentrics mounted

on a central shaft passing through the upper part of the main casting as shown at *B*. These eccentrics, which are connected to the tool posts by means of short links shown at *A*, are set at an angle of 180 deg., so that angular motion of the shaft will cause both the tool posts to advance into or recede from the work together. Mounted loosely on the opposite end of the central shaft bearing is a gear wheel, and on a sleeve extending from the boss of this wheel is screwed a ratchet-toothed cam seen in the figure at *A* and *D*. The cam is driven from the nose of the lathe by means of a shaft having two universal joints. The cam rotates at the same speed and in the same direction as the work and must have the same number of teeth as the tool being relieved. The actual diameter of the cam and the shape of the teeth are immaterial, but the teeth may be formed with feather edges.

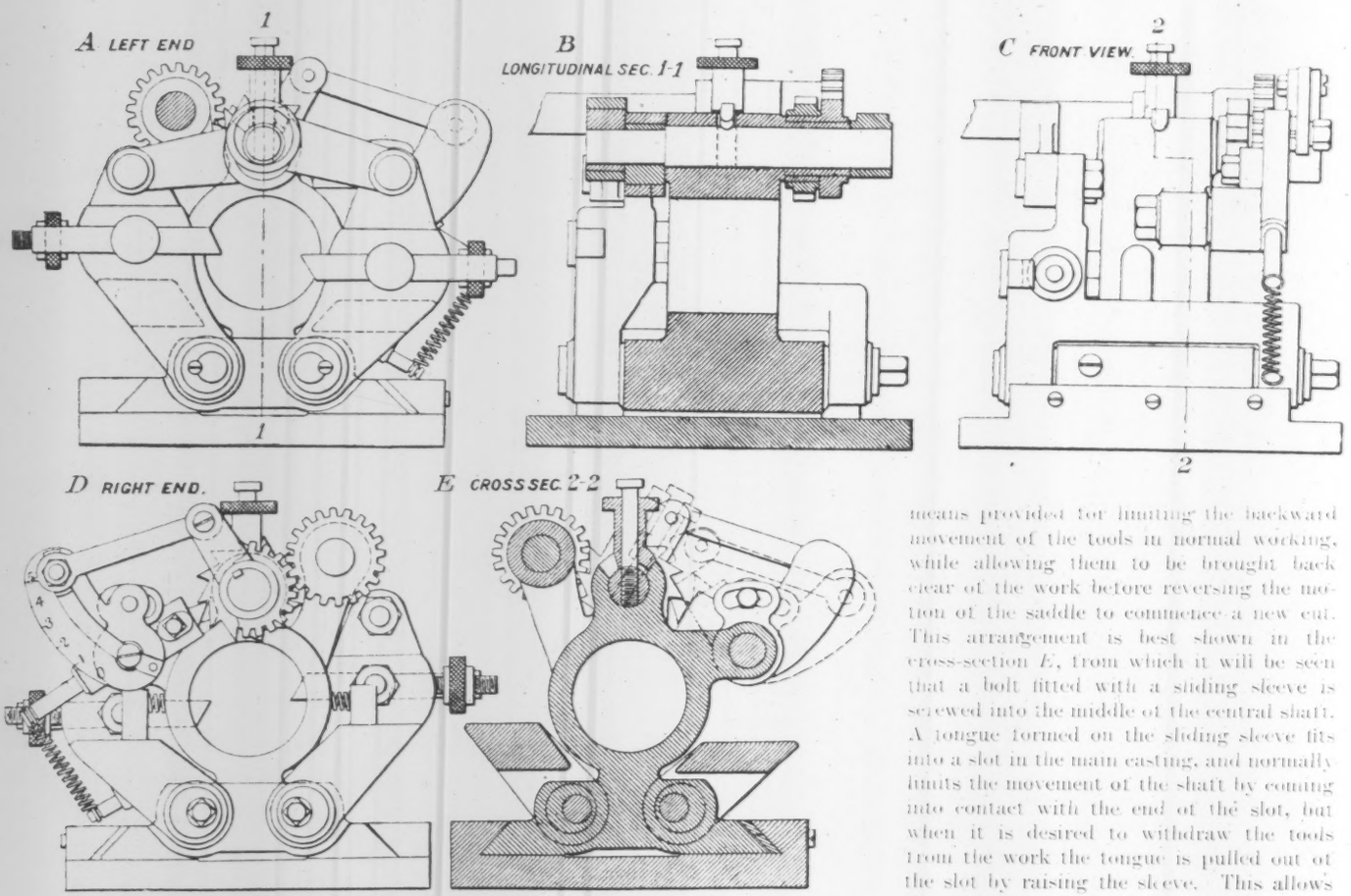


FIG. 8 MILTON RELIEVING ATTACHMENT FOR LATHES

Reamers and cutters in which the teeth are unequally spaced can be relieved by means of the attachment, but in such case the teeth of the cam must, of course, be spaced to correspond with those of the work.

Referring now to *D*, it will be noticed that the teeth of the cam engage with an adjustable pawl mounted on one arm of a bell-crank lever, which is pivoted on the main casting. As the cam rotates in anti-clockwise direction the arm of the bell-crank lever will be pulled downward until the pawl escapes from the tooth of the cam, when it will be pulled up into engagement with the next tooth by the action of a light helical spring seen in both illustrations. The combined effect of the cam and spring is thus to impart an oscillating motion to the bell-crank lever. On the other arm of the latter is formed a segmental groove, and in this groove a block, to which a short link is pivoted, can be clamped in any position. The other end of the link is connected to an arm keyed on to a central shaft, above referred to, and in this way the oscillating motion of the bell-crank lever is communicated to the central shaft, and also, through the eccentrics, to the tool posts. Two short springs fitted between projections on the forked parts of the tool posts and the main casting are provided in order to take up any lost motion due to wear of the links, etc.

It will be obvious that the position of the block in the segmental groove determines the magnitude of the angular oscillations of the central shaft, and consequently those of the tool posts, so that, by adjusting the block, the amount of relief can be varied at will quite independently of the shape of the cam. The actual amount of relief is indicated by a scale engraved on the arm of the bell-crank lever, as shown at *D*, the figures giving the amount of relief in millimeters. The only other feature of the mechanism now remaining to be explained is the means provided for limiting the backward movement of the tools in normal working, while allowing them to be brought back clear of the work before reversing the motion of the saddle to commence a new cut. This arrangement is best shown in the cross-section *E*, from which it will be seen that a bolt fitted with a sliding sleeve is screwed into the middle of the central shaft. A tongue formed on the sliding sleeve fits into a slot in the main casting, and normally limits the movement of the shaft by coming into contact with the end of the slot, but when it is desired to withdraw the tools from the work the tongue is pulled out of the slot by raising the sleeve. This allows the spring attached to the bell-crank lever to pull the latter back into the position indicated by the dotted lines in *E*. In this position the tools will be quite clear of the work and the pawl clear of the cam; the lathe can then be reversed without altering the adjustment of the tools in the tool holders. This is a great advantage when relieving screwed hobs, and is also convenient for ordinary screwing without relief.

An important advantage of the pivoting tool holder in comparison with the horizontal slide of the ordinary relieving lathe, is that, in the former, the tools can be adjusted so that the cutting angle remains constant at all parts of the cut, and consequently greater cutting efficiency is attained and a tool with much less clearance can be used. That it is necessary to tilt the tool for this purpose will be obvious when it is remembered that the normal relief to the curve at the cutting edge of the tooth being formed coincides with the radius of the plain cylindrical blank, since no metal is removed from this part of the tooth, whereas, at the inner end of the curve, the normal is inclined by an amount depending upon the amount of relief. In an ordinary relieving lathe, in which the tool moves horizontally, no allow-

ance is made for this feature, and the cutting angle may therefore vary by 15 deg. or 20 deg. from one end of the relief curve to the other. Another advantage of the pivoted tool holder is that the friction is considerably less than that of a sliding holder, and consequently a greater proportion of the power supplied is available for the cut in the former system. It is also pointed out that the fact that the tool holder is operated from a point well above the tool gives great rigidity in cutting.

By illustrations and descriptions the original article shows the large variety of work which can be done by means of this attachment. (*Engineering*, vol. 109, no. 2828, Mar. 12, 1920, pp. 345-346 and 348, 11 figs., *d*)

## MARINE ENGINEERING

### Largest and Fastest Battle Cruiser Afloat in Any Navy

BRITISH BATTLE CRUISER "HOOD." Some data of the new battle cruiser *Hood*, built by John Brown & Co., Clydebank, which is said to mark the close of a period in naval history. The ship was intended to be one of a group of four, but is the only one to reach completion and is today the greatest unit afloat in any navy in existence.

The *Hood* was built under conditions of unusual difficulty. The builders were furnished with sketches of preliminary design in April, 1916, and the ship was launched on August 22, 1918, a highly creditable performance considering that the first keel plate was not laid until September, 1916.

In many features the ship heralds a new departure. The difference in structure that strikes the eye first (as compared with the existing battle cruisers) lies in the "bulge" or "blister" which secures the ship against effective attack by a torpedo. This blister surrounds the main hull of the ship, and has been carefully proportioned in order to reduce to a minimum the additional resistance it causes.

The use of the blister involved many interesting problems of design. Thus, the subdivisional bulkheads have been so arranged that the energy of an external explosion is absorbed at the spot, thus preventing the piercing of the main hull should the outer hull be blown in by the explosion.

The armor has been disposed so as to provide a protection against shell fire to the vitals of the ship. The deck over the magazines is 3 in. thick. The side armor is fitted in three tiers, the lowest of which is 12 in. thick amidships, tapering to 6 in. and 5 in. forward and aft. Above the main 12-in. plate the middle and upper tiers are respectively 7 in. and 5 in. thick, while the conning-tower armor is 11 in. in thickness.

The main armament of the ship consists of eight 15-in. guns, all on the middle line. Each pair of guns is mounted in an armored barbette. The barbette armor is 12 in. thick. The gun shields are 15 in. thick in front and 11 in. thick at the sides.

The secondary armament consists of twelve 5.5-in. guns, five of which are mounted on each side of the vessel on the forecastle deck, the remaining two being mounted on the top of the superstructure. All these 5.5-in. guns are protected by gun shields forming an integral part of the mounting. In addition there are four 4-in. anti-aircraft guns also mounted on the superstructure.

The propelling machinery comprises four distinct sets, each driving one shaft, arranged in three engine rooms. The turbines are of the Brown-Curtis type and each set of machinery consists of compound ahead turbines driving the propeller shafting through single reduction gearing. For use at cruising speeds a cruising turbine of the Brown-Curtis type is provided. This has a separate casing and can, at will, be connected to, or disconnected from, the main high-pressure turbine shaft by suitable clutches. At cruising speed this turbine is operated in series with the high-pressure and low-pressure turbines of the set.

The reverse turbine is fitted with the low-pressure casing and rotates in a vacuum when the ship is running ahead. Each of the four sets of machinery is complete in itself with its own condenser and auxiliaries and can be used independently.

Each high-pressure ahead turbine rotor consists of ten wheels, of which the first and second are velocity-compounded having two rows of blades each, and the remainder are simple impulse wheels. Each low-pressure ahead-turbine rotor consists of eight wheels, of the simple impulse type. Each cruising-turbine rotor has four velocity-compounded wheels with three rows of blades on the first wheel and two rows on each of the others. The astern turbine for each shaft is incorporated in the low-pressure ahead-turbine casing and consists of two velocity-compounded wheels, each carrying three rows of blades.

The turbine casings are of cast iron with the nozzle-control-valve seatings cast in the body. The rotor spindles are of forged steel, having a tensile strength of 34 tons to 38 tons per sq. in. The wheels are of forged steel, of similar quality, and phosphor bronze has been used for the blades, which are of the usual impulse type. The blades have dovetailed roots, and the tips of the blades are supported by phosphor-bronze shrouding. The diaphragms are of cast iron, with the nozzle blades of nickel steel (about 3½ per cent nickel) cast in. The diaphragms in the cruising turbines and the first diaphragm in the high-pressure turbines are solid, the remainder of the diaphragms in the high-pressure turbine, and those in the low-pressure turbines, being split. The spindle is made steamtight where it passes through the diaphragms by segmental serrated brass rings, kept up to their work by garter copper-coated steel springs in the cruising and the first diaphragm of the high-pressure turbines, and by sherardized coach springs in the other diaphragms of the high-pressure and in the low-pressure turbines. The glands are packed, as is usual in Brown-Curtis turbines, with carbon rings made in segments and held in position by springs. The high-pressure ahead forward-end gland has eight carbon rings, the after end five, the low-pressure ahead four rings and the astern turbine four rings. The cruising turbine is fitted with five rings in each of the glands.

The turbines are designed to develop a total horsepower of 144,000 with about 210 lb. pressure in the control chest and 28 in. vacuum in the condensers. Steam is supplied by 24 Yarrow-type small-tube boilers burning oil fuel and located in four compartments. The working pressure is 235 lb. per sq. in. and the heating surface per boiler 7290 sq. ft.

The original article is illustrated by a number of plates giving an idea of the stupendous size of the unit itself and its various details. (*Engineering*, vol. 109, no. 2830, Mar. 26, 1920, pp. 397-399 and 4 pp. of plates, 12 figs., *dA*)

## MILITARY ENGINEERING (See Hydraulic Machinery)

## MEASURING INSTRUMENTS

THE SIGNALING PYROMETER, R. P. Brown. The ordinary pyrometer which either indicates on a temperature scale or records the temperature on a chart is satisfactory where the employees are capable of reading the temperature scale or understand the movement of the pointer. During the last few years, however, an inferior grade of labor has had to be employed, often unable to understand the instrument, and it has become necessary, therefore, to use some other means to indicate to the furnace operator when the temperature is correct or too high or too low.

In some plants this is done by signaling the temperature by lights from one central station. Three lights are grouped at each furnace: green, to indicate that the temperature is too low; white, correct; and red, too high. This system requires, however, the maintenance of a central operator to flash the signals and usually an elaborate switchboard and wiring system from the furnaces to the central station.

Recently, however, an instrument has been developed to operate the signal lights from a pyrometer automatically. In this instrument, whose construction is very similar to that of the ordinary indicating pyrometer, a contact table adjustable throughout the whole scale range carries three contacts corresponding to the three lights, the central contact operating the white light, usually covering a space of 20 deg. on the scale, amounting to 10 deg. above or below the desired temperature. The pointer on the

pyrometer is automatically depressed once a minute on the tungsten contacts.

An automatic three-position relay is operated by the closing of the contacts in the instrument. Let us assume that the furnace is started up and the low contact is closed, corresponding to the green light, and the relay complete the circuit through the green light. The contact in the instrument is only closed a few seconds to operate the relay, but the green light continues to burn until the temperature rises to the desired point, when the relay shifts, causing the white light to burn and extinguishing the green light. The proper light continues to burn at all times, although the contact in the instrument only closes for a few seconds once a minute. (*Journal of American Steel Treaters' Society*, vol. 1, no. 4, Jan. 1919, pp. 131-132, *d*)

## MOTOR-CAR ENGINEERING

MOTOR SLED. Description of a motor sled now being perfected by a company in Seattle, Wash.

The propelling force is obtained by applying the principle of the ship propeller to two revolving drums turning in opposite directions and having secured to them a series of spirals that force the sled ahead just as a bolt is forced through a nut when turning. The speed of the sled is changed by a special transmission through a conventional gear shift.

The fact that the propelling drums rotate in directions opposite to one another makes it necessary to employ a special gear drive. In this case it has three gears, the drive pinion from the engine directly meshing with only one of these gears. The lower two gears again mesh with one another and drive through separate shafts to centrally located sprockets and then through chains to the main-drive sprockets located in between the two drums.

Finally, the drums must be made perfectly cylindrical in shape in every transverse section and must be perfectly smooth.

It is claimed that there is absolutely no slip between the snow surface and sled.

In other words, for a given number of revolutions of the drum with a certain pitch of the skates, the actual travel is equal to the theoretical length of the travel.

The drums are made of pressed steel fastened by means of flanges and spiders to the drive shaft. The steel skates spirally located on the drum are of a very shallow depth—probably not over $\frac{5}{8}$ in. high.

In addition to this, there are two vertical guides fastened on to the superstructure of the car, the object of which is to keep the drum shafts parallel in a vertical plane and also to allow the drums and drum shafts which are supported on a central pivot to oscillate around this point in order to conform to the road bed. (*Motor Age*, vol. 37, no. 12, Mar. 18, 1920, p. 30, 1 fig., *d*)

### Laxtonia Twin-Six Motor-Car Engine; Angle of "V" and Vibration of Engines

BRITISH TWIN-SIX MOTOR-CAR ENGINE. Description of the 12-cylinder touring-car engine designed by W. L. Adams of the Laxtonia Engineering Company, Peterborough, England.

The engine has several interesting features. The two blocks of six cylinders (Fig. 9) have an angle of 30 deg. between them. Such an arrangement is apt to increase vibration but makes the engine more compact, which, in this case, is further enhanced by the fact that the cylinder blocks are cast with the main portion of the crankcase as a single unit in aluminum.

The 30-deg. setting also simplifies the design as it enables a single overhead shaft midway between the two blocks to operate all the overhead valves, both inlet and exhaust, through the medium of rockers.

The crankshaft (Fig. 10) has only three throws and two journal bearings of the roller type. Two bearings are considered to be sufficient because the crankpins and journals are of $2\frac{3}{4}$ in. diameter and the individual impulses are claimed to be of comparatively small magnitude.

A detachable cylinder head is fixed over each block of cylinders and carries the overhead valves. Each block of cylinders is staggered in relation to the other, to the extent of 21/32 in.,

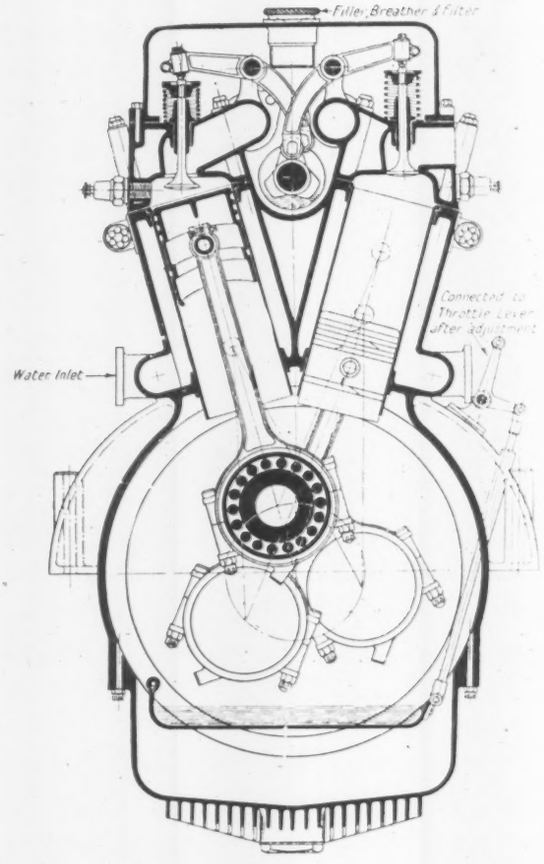


FIG. 9 SECTION OF THE LAXTONIA 12-CYLINDER ENGINE

which allows the connecting rods of opposing pairs to lie side by side without their being offset in relation to the piston centers.

The overhead camshaft formed in one piece with its 24 cams

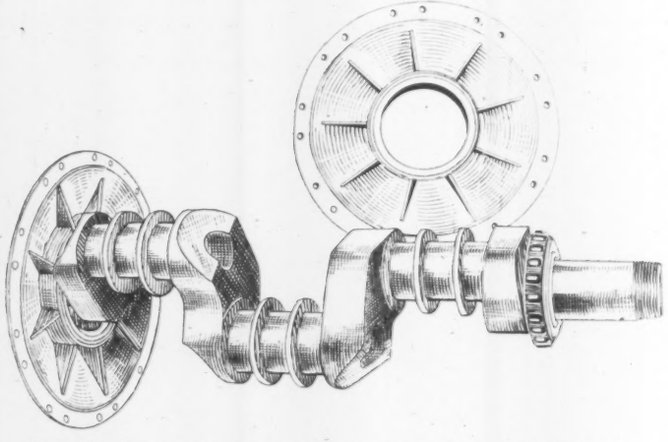

FIG. 10 CRANKSHAFT OF THE LAXTONIA 12-CYLINDER ENGINE

is driven by a train of three spur pinions enclosed at the front of the engines and lies in a trough formed above the main casting. The oil pump delivers oil through the branch pipe to this trough and the rotating cams serve to distribute lubricant to all the overhead gear, which is enclosed by a detachable aluminum cover.

While the engine has a capacity of 6900 cu. cm. (421 cu. in.) the two cylinder blocks are but 12 in. overall.

While it is admitted that the uniformity of turning effort in this engine falls below that of a 60-deg. twelve, its torque curve approaches that of the 12-cylinder Liberty engine, which has its cylinder blocks set at an included angle of 45 deg. There are two peaks in the torque curve of every 120 deg. of crankshaft revolution, the minor peak occurring 30 deg. in advance of the main peak. (*The Engineer*, vol. 129, no. 3349, March 5, 1920, pp. 252-254, 4 figs., *d*).

## POWER PLANTS

### Principles of Standardization of Power Plants: Suggested Types of Standard Units

STANDARDIZATION OF POWER PLANTS, Louis R. Lee. Standardization is recommended in the interests of plant efficiency, which the author defines as the ratio of the gross input to the gross output. The gross output may be expressed in pounds of steam or in kilowatt-hours. In the first case the efficiency ratio should be effected only when they will not reduce the possible saving in operation and maintenance.

Fig. 11 shows several types of assembly of the complete unit and the different possible building arrangements. In *B* the plant shows the boilers, economizers and auxiliaries are housed in the main building, while the induced-draft equipment, coal bunkers and ash discharge are outdoors.

In *C* and *D* a reduction in size of the main building is secured by providing each economizer unit with a self-containing waterproof covering, this covering also extending over the aisles between economizers.

It is claimed that a comparison of any of these building arrangements with the best present-day practices will show much saving in cubical contents of the building when compared on a rate of horsepower basis. There is also a great saving in material for supporting equipment particularly the economizers and draft equipment.

The standard unit as designed by the author consists of a cross-drum boiler set singly with suitable stoker furnace and provided with a direct-connected economizer. The draft equipment consists of a forced-draft fan and an induced-draft fan, both motor-

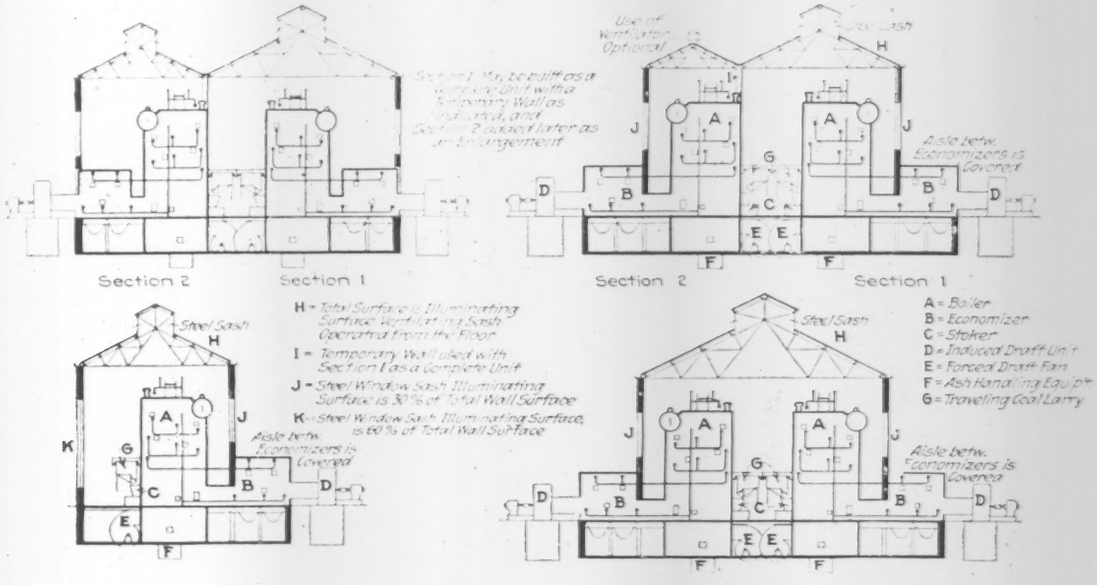
Section 2
Section 1
Section 2
Section 1
Steel Sash
H = Total Surface is Illuminating Surface, Ventilating Sash Operated from the Floor
I = Temporary Wall Used with Section 1 as a Complete Unit
J = Steel Window Sash, Illuminating Surface is 30% of Total Wall Surface
K = Steel Window Sash, Illuminating Surface is 60% of Total Wall Surface
Aisle betw. Economizers is Covered
A = Boiler
B = Economizer
C = Stoker
D = Induced Draft Unit
E = Forced Draft Fan
F = Ash Handling Equipt.
G = Traveling Coal Larry

FIG. 11 SECTIONAL VIEWS OF SOME STANDARDIZED BOILER PLANTS AS DESIGNED BY LOUIS R. LEE. UPPER LEFT, *B*; LOWER LEFT, *C*; UPPER RIGHT, *D*; LOWER RIGHT, *E*

show the cost per thousand pounds of steam and in the latter case per kilowatt-hour, the cost of input covering all that is actually put into the plant, including cost of fuel, labor for operating, labor for maintenance and fixed charges on the total investment.

One of the most essential parts of all power plants is the boiler plant. The boiler complete with furnace draft equipment and feedwater supply is essentially a complete plant and it is only necessary to multiply the output of such a unit to secure any desired output. By making the unit a complete fractional part of a plant extensions are taken care of with minimum trouble and cost.

To make estimating of the cost of the installation easier and also to effect savings the author recommends devising the unit design with the limited selection of characteristic equipment bearing in mind the effect that the price of the fuel has on the installation.

Unless necessitated by local conditions such as occur in congested city districts, it is recommended in the design to use more ground area rather than high elevation. To secure low operating cost all equipment must be so located that all parts are quickly accessible and the disassembly is easily effected for making repairs and maintenance. Savings in first cost of construction must

driven. The induced-draft equipment together with stack is located outdoors where space permits, and inspection of the fan is obtained through a doorway opposite each unit aisleway for which the width of 10 ft. is recommended as standard.

A central observing and controlling station is provided at each side of the boiler unit, these stations being arranged where desired, right and left hand, so that one operator may observe and control two units. Data as to the equipment and details of the apparatus used are also given. (*Power*, vol. 51, no. 10, Mar. 9, 1920, pp. 375-378, 2 figs., *gd*)

## RAILROAD ENGINEERING (See Engineering Materials)

## WOOD (See Engineering Materials)

## CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society. The Editor will be pleased to receive inquiries for further information in connection with articles reported in the Survey.

# ENGINEERING RESEARCH

## A Department Conducted by the Research Committee of the A. S. M. E.

### A—Research Results

The purpose of this section of Engineering Research is to give the origin of research information which has been completed, to give a résumé of research results with formulæ or curves where such may be readily given, and to report results of non-extensive researches which in the opinion of the investigators do not warrant a paper.

*Apparatus and Instruments A5-20* Accuracy of Chronographs. The use of photographic records to determine the uniformity of motion of clockwork used to drive recording mechanism and to determine the uniformity of chronographs has been developed by the Bureau of Standards. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

*Apparatus and Instruments A6-20* Anemometer. An air-speed indicator of the Robinson cup type with centrifugal indicating mechanism has been calibrated. This instrument is of German manufacture and is very compact and well adapted for use on dirigibles. It is independent of changes in air density and gives actual air speeds. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

*Apparatus and Instruments A7-20* The Leucoscope Used in Pyrometry. The Bureau of Standards has found that the leucoscope of Helmholtz is applicable to pyrometry and spectral energy distribution in a light source or furnace. These data have been communicated to the Optical Society of America and will appear in its Journal. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

*Apparatus and Instruments A8-20* New Instrument for Measuring Small Air Velocities. Thesis by A. E. Reinhard and J. R. Cain, Rose Polytechnic Institute. Use of the standard pitot tube with instrument for measuring the difference of pressures.

Two shallow, airtight tin boxes about 6½ in. square have square openings about 6⅛ in. on a side cut in the tops. Within each opening a square aluminum plate, 5⅜ in. on a side, is located so as to be central and in the plane of the top of the box. Thin gold leaf is then cemented to the aluminum plate and to the top of the box so as to make an airtight receptacle with a flexible top.

A suitable wooden base is provided with a column for supporting an equal-arm balance, which is sensitive to one grain. The air boxes are fastened to the base so that the centers of the boxes are vertically below the respective ends of the balance lever, and the aluminum plates are connected by suitable cords with the arms of the balance. Suitable stops are also provided for limiting the movement of the diaphragm so as to prevent tearing the gold leaf.

When the air boxes are connected respectively to the dynamic and the static sides of the pitot tube, the net effect upon the balance is due to the pressure equivalent of the air velocity which is being measured. The scales are first balanced with both air boxes open to atmosphere. Then connections are made to the pitot tube and weights added until a balance is again obtained. The added weight divided by the effective area of the diaphragm gives an absolute measure of the difference of pressure.

The instrument was found to be sensitive enough to record a velocity of 1½ ft. per sec. At 3 ft. per sec. the probable error was about 3 per cent. This instrument is not suited to high velocities. It was used successfully to measure velocities between 1½ and 15 ft. per sec.

Address Prof. F. C. Wagner, Rose Polytechnic Institute, Terre Haute, Ind.

*Internal-Combustion Motors A2-20* Monel Metal for Engine Valves. The Bureau of Standards has recently used exhaust valves made of monel metal in a 180-hp. Hispano-Suiza engine during 130 hr. of running time. The tests were of 6 hr. duration. During this period 90 hr. of the test were devoted to the study of lubricating oils while the engine ran at 1800 r.p.m. and developed 130 to 140 hp. At the end of 45 hr. the valves were found to be badly pitted and the valve seats were found to be in the same condition. During the next 45 hr. the power was the same as before and after this the valves were opened for 40 hr. service under severe conditions while the engine was used to study preignition. High temperatures were experienced and the electrodes of the spark plugs were fused, the melting point being in the neighborhood of 1500 deg. cent. In spite of this severe test the valve seemed to hold up as there was no drop in power. The valves were found to remain red for nearly a minute after the valves in the other cylinders had become black. The pitted appearance of the valves does not seem to affect the gas tightness. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

*Chemistry, Organic A1-20* Camphor. A new step in the process of manufacture of synthetic camphor from pinene (turpentine) has been studied by the Institute of Industrial Research. Camphor is a necessary constituent in the manufacture of celluloid and allied compositions, and is used in the manufacture of moving-picture films. Up to the present time camphor is an almost exclusive Japanese monopoly. Institute of Industrial Research, 1845 B. St., N. W., Washington, D. C. Address Allerton S. Cushman, Director.

*Metallurgy and Metallography A4-20* Zirconium. A new process for treating zirconia and zirconite ores so as to get them into a condition in which they are readily soluble in acids for reprecipitation and purification, has been developed by the Institute of Industrial Research. Since zirconia is of great present interest on account of its extraordinary refractoriness at high temperatures, this process may prove of value. The Institute of Industrial Research, 1845 B. St., N. W. Washington, D. C. Address Allerton S. Cushman, Director.

*Metallurgy and Metallography A5-20* Mechanical Hardness and Grain Size of Carbon Steels. The research just completed at the Bureau of Standards shows no simple relation between grain size and hardness in carbon steels such as exists in alpha-brass and other constituent alloys. Grain size is a factor of minor importance. The amount of distribution of structural constituents determines the hardness to very great extent. The work already completed throws some light upon the magnitude of the stressing of low-carbon steel by cooling and the work in order to affect subsequent grain growth upon annealing below the critical temperature. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

*Petroleum, Asphalt and Wood Products A1-20* Iroline Process. A new process known as the Iroline Process for treating heavy petroleum oils and distillates in order to produce light, low-boiling hydrocarbons of a gasoline-like nature, has been developed by the Institute of Industrial Research. This process has been given a trial on the plant scale of operation in a specially designed plant capable of treating 1000 bbl. of distillate per day. The results obtained were satisfactory. The Institute of Industrial Research, 1845 B. St., N. W., Washington, D. C. Address Allerton S. Cushman, Director.

*Refrigeration A1-20* Ammonia Vapor Pressure. A paper has been published in the Journal of the American Chemical Society, vol. 42, p. 206, giving a summary of the research made at the Bureau of Standards on the vapor pressure of ammonia from —78 deg. cent. to + 70 deg. cent. Seven samples of thoroughly purified ammonia were used. Special tests showed less than one part in 100,000 by volume of non-condensing gases and less than 1/100 per cent by weight of other impurities. The commercial samples of ammonia were found to give hysteresis due to the presence of impurities. The normal boiling point was determined by static and dynamic methods. Two empirical equations were found to represent the results for the temperature range covered with close agreement to actual results. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

### B—Research in Progress

The purpose of this section of Engineering Research is to bring together those who are working on the same problem for coöperation or conference, to prevent unnecessary duplication of work and to inform the profession of the investigators who are engaged upon research problems. The addresses of these investigators are given for the purpose of correspondence.

*Internal-Combustion Motors B4-20* Kerosene Vaporizer. The development of a kerosene vaporizer for use on gasoline engines to be inserted between an ordinary carburetor and intake manifold in which wet mixture is added by passing part of exhaust gas through tubular heater. From investigations so far conducted the device appears to show more power and better efficiency than

that obtained from gasoline with the ordinary carburetor. There is freedom from knocking, no contamination of the lubricating oil and no greater sooting or carbonizing. Freedom from smoke requires careful handling. Address Prof. E. F. Church, Polytechnic Institute, Brooklyn, N. Y.

*Heating B5-20* Test on Vapor-Pressure Regulating Valves for Heating Systems. A study of the fluids used in various types of vapor-pressure control valves with tests of their action in use on heating systems. Address Prof. E. F. Church, Polytechnic Institute, Brooklyn, N. Y.

*Metallurgy and Metallography B4-20* Expansion of Low-Carbon Chrome-Nickel Steel. A study of the expansion of low-carbon chrome-nickel steel during heat treatment is being carried out at the Michigan Agricultural College at East Lansing. Address Prof. H. B. Dirks.

*Metallurgy and Metallography B5-20* Expansion and Contraction of Steel by Heat Treatment. The expansion and contraction of steel by heat treatment as in the problem of the shrinkage of oversized holes and the expansion of undersized pins and disks is being carried out in the Michigan Agricultural College, East Lansing, Mich. Address Prof. H. B. Dirks.

*Properties of Engineering Materials B11-20* Effect of Temperature on Tensile Strength of Muntz Metal, Bronzes and Steel. Tests on the ultimate strength and ductility of various materials at temperatures from 20 deg. to 550 deg. cent., including effects of annealing, cold-rolling, extrusion and such actions in relation to strength at high temperatures. Address Prof. E. F. Church, Polytechnic Institute, Brooklyn, N. Y.

## D—Research Equipment

The purpose of this section of Engineering Research is to give in concise form notes regarding the equipment of laboratories for mutual information and for the purpose of informing the profession of the equipment in various laboratories so that persons desiring special investigations may know where such work may be done.

*Michigan Agricultural College D1-20* Mechanical Engineering Department.

Exhaust fan and heater stacks
Material-testing machines for tension, compression and torsion
12-in. by 30-in. Nordberg Corliss engine
8-in. by 12-in. Skinner automatic cut-off engine
75-kw. Terry turbine direct-connected to d. c. generator
12-in. by 7½-in. by 14-in. Sullivan tandem compound steam-driven air compressor
6-in. by 6-in. Ingersoll-Rand Imperial-type air compressor
Condensers, pumps and injectors
8½-in. by 12-in. tandem compound Elyria gas engine
Horizontal and vertical gasoline engines
50-hp. cradled motor
Single and three-stage centrifugal pumps
16-in. Pelton water wheel
Venturi meter and weirs
Hardening and tempering furnaces, scleroscopes and Brinell hardness-test machines
Leeds and Northrup pyrometer equipment
Leeds and Northrup transformation point apparatus
Bausch and Lomb microscopes and cameras for microphotographs
Electric furnaces with pyrometers
Gas-fired crucible furnaces
One-ton cupola
Motor-driven machine tools

## E—Research Personal Notes

The purpose of this section of Engineering Research is to give notes of a personal nature regarding the personnel of various laboratories, methods of procedure for commercial work or notes regarding the conduct of various laboratories.

*Petroleum Asphalt and Wood Products E1-20* Petroleum Stills. Mr. Henry Kreisinger has just completed an investigation on the furnace conditions and heat transmission in petroleum stills for the Bureau of Mines. This work will soon be ready for publication. Bureau of Mines, Washington, D. C. Address Van R. Manning, Director.

The Bureau of Mines has received the following monthly reports of investigations for March, 1920:

Manufacture of Carbon Black from Natural Gas, by Roy O. Neal
Records of Individual Wells, by A. W. Ambrose
Recent Articles on Petroleum and Allied Substances, by E. H. Burroughs
Comparison of British and American Coal-Mining Conditions, by G. S. Rice
Decrease in Coal-Mine Accidents, by W. W. Adams
Sulphur in Coal and Coke, by Alfred R. Powell
Diatomaceous Earth, by W. C. Phalen
Marble in Guatemala, by Oliver Bowles
Asbestos, by Oliver Bowles
General Aspects of the Leasing Law, by James R. Jones
Employee Representation in Mining Enterprises, by T. T. Read
Observations with the Geophone, by Alan Leighton
Automobile Exhaust Gases in Vehicular Tunnels, by A. C. Fieldner.

Bureau of Mines, Washington, D. C. Address Van R. Manning, Director.

## F—Bibliographies

The purpose of this section of Engineering Research is to inform the profession of bibliographies which have been prepared. In general this work is done at the expense of the Society. Extensive bibliographies require the approval of the Research Committee. All bibliographies are loaned for a period of one month only. Additional copies are available, however, for periods of two weeks to members of the A.S.M.E. or to others recommended by members of the A.S.M.E. These bibliographies are on file in the offices of the Society.

*Calorimetry, Pyrometry, Thermometry F1-20* Treatise on Pyrometric Practice. The Bureau of Standards has completed a comprehensive treatise on modern pyrometry. This volume will consist of 300 pages, with a large number of illustrations. It will be ready in nine months and may be obtained at cost from the Superintendent of Documents, Washington, D. C. Bureau of Standards, Washington, D. C. Address S. W. Stratton, Director.

*Mining, General F1-20* A Glossary of the Mining and Mineral Industry, by Albert H. Fay of the Bureau of Mines, 754 pp. Bureau of Mines, Washington, D. C. Adrress Van R. Manning, Director.

*Light F1-20* Nomenclature of Chromatics and Colorimetry. The Bureau of Standards has prepared a draft of a report on nomenclature and standards of colorimetry. It was submitted to the Optical Society of America. The draft has 50 pages and the following table of contents:

Introduction
Nomenclature, including General Terminology
Fundamental Psychologic Terms; Outline of the Methods of Practical Colorimetry; Classification of the Methods of Measurement Contributory to Colorimetry; Terms Relating to Transmission; the Physical Terms of Homo-hetero-analysis and their Correlation with the Attributes of Color
Standards, including Standards of Spectral Energy Distribution; Transmission Standards
Bibliography
Usage of Terms Relating to the Attributes of Color and their Correlations in Stimulus
Usage of the word "Light."

The report may be borrowed from the Bureau of Standards, Division 4, Section 3, Washington, D. C.

*Petroleum, Asphalt and Wood Products F2-20* The Bureau of Mines has prepared a bibliography of the recent articles on petroleum and other allied substances, by E. H. Burroughs. Bureau of Mines, Washington, D. C. Address Van H. Manning, Director.

*Textile, Manufacture and Clothing F1-20* Drying of Textiles on Tentering or Stentering Machines. A bibliography of one-half page. Search 2904. Address A.S.M.E., 29 West 39th St., New York.

*Transmission F2-20* Roller Bearings. A bibliography of 10 pages. Search 2654. Address A.S.M.E., 29 West 39th St., New York.

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In experiments on gravitation reported by L. Majorana (*Comptes Rendus, Acad. des Sciences*, vol. clxix, Nos. 15 and 17, 1919), a lead sphere of mass 1274 g. suspended from the right arm of a balance was counterpoised by a similar sphere on the left arm. Both spheres were surrounded by walls of the same shape. The first sphere had its center coincident with the center of a cylinder with vertical axis which could be filled with mercury of mass 104 kg. The liquid was kept from touching even the protecting wall about the lead sphere. A vacuum was maintained within the balance case and all thermal, electrical, magnetic, and electromagnetic effects were eliminated. As the result of a lengthy series of experiments, it was found that the lead suffered a loss of weight of 0.0009 mg. when it was surrounded by the mercury, that is, a loss of $7.10^{-10}$ of its own weight. This is of interest, since hitherto it has been believed that the force of gravity acts through matter just as if it were a vacuum.

# Work of the Boiler Code Committee

*THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, Mr. C. W. Obert, 29 West 39th St., New York, N. Y.*

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society for approval, after which it is issued to the inquirer and simultaneously published in MECHANICAL ENGINEERING, in order that any one interested may readily secure the latest information concerning the interpretation.

Below are given the interpretations of the Committee in Cases Nos. 253, 268, 270, 279, 283-290, inclusive, as formulated at the meeting of March 18, 1920, and approved by the Council. In accordance with the Committee's previous practice, the names of inquirers have been omitted.

### CASE NO. 279

*Inquiry:* Is it permissible under the requirements of the Boiler Code to construct steel heating boilers in diameters up to 72 and 78 in. with shell plates ¼ in. in thickness? Is it the opinion of the Committee that boilers of the h.r.t. type so constructed have sufficient shell plate strength to permit of proper lug attachments for support of the shell?

*Reply:* The section of the Code on Heating Boilers is incomplete in not specifying the minimum plate thickness to be used in the shells and tube sheets, and below which the thickness shall not be made in any case. The Boiler Code Committee recommends that until a revision be made to cover this class of boiler construction, the minimum thickness of shells and heads for various shell diameters of steel plate heating boilers shall be as follows:

| Diameter of Shell, Tube Sheet or Head | Minimum Thickness Allowable Under Rules | |
|---|---|---|
| | Shell, in. | Tube Sheet or Head, in. |
| 42 in. or under | ¼ | 5/16 |
| Over 42 in. to 60 in. | 5/16 | 3/8 |
| Over 60 in. to 78 in. | 3/8 | 7/16 |
| Over 78 in. | 7/16 | ½ |

### CASE NO. 283

(In the hands of the Committee)

### CASE NO. 284

*Inquiry:* Is it the intent of Pars. 269 and 270 of the Boiler Code that a boiler requiring safety valve relieving capacity greater than 2000 lb. per hour shall have two safety valves, each one of which alone will properly discharge the steam, or does it require two safety valves, the combined capacity of which will properly discharge the steam?

*Reply:* For capacities greater than 2000 lb. per hour, the Code requires two or more safety valves on each boiler, the combined capacity of which shall meet the requirements of Par. 270.

### CASE NO. 285

*Inquiry:* Is it permissible under the rules of the Boiler Code to use standard extra-heavy cast-iron flanges and fittings on pipe connections between boilers and attached-type superheaters, and on the ends of superheater-inlet headers for pressures up to 250 lb. per sq. in.? It is pointed out that neither the inlet pipe connections nor the superheater inlet flanges would be subjected to other than saturated steam temperatures.

*Reply:* It is the opinion of the Committee that the flanges referred to may be made of cast iron, provided the temperature of the steam does not exceed 450 deg. fahr., as specified in Par. 12.

### CASE NO. 286

*Inquiry:* Does Par. 321 of the Boiler Code require that all water column connections to boilers must be fitted with crosses for cleanout purposes, or is it permissible in a connection of a water column to a steam drum as shown in Fig. 5 to omit the crosses, provided provision for cleanout is afforded by the gage glass connection on the opposite side of the water column?

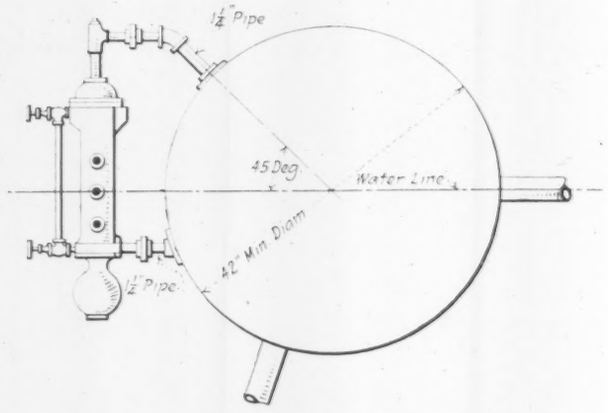


FIG. 5 CONNECTION OF WATER COLUMN TO SIDE OF DRUM OF WATER-TUBE BOILER

*Reply:* It is the intent of Par. 321 that a cross be applied at a right-angle turn in the water connection to a column for purposes of cleaning. Where an easily accessible straight pipe connection is used without a turn, the cross is obviously not needed.

### CASE NO. 287

(In the hands of the Committee)

### CASE NO. 288

(In the hands of the Committee)

### CASE NO. 289 (Revision of Case No. 254)

*Inquiry:* Does the reply to Case No. 254 apply only to flat plates or also to the holes in the shells of drums?

*Reply:* This Case applies to flat sheets. It is not permissible to burn tube or other holes into the shells of drums unless such holes are strengthened with flange or other reinforcements.

### CASE NO. 290

*Inquiry:* In determining the ratios of lengths between supports to diameter in Table 5, is the diameter at the root of the thread to be used, or the diameter of the body of the stay.

*Reply:* It is the opinion of the Committee that the diameter of the body of the stay is to be used in determining this ratio.

# CORRESPONDENCE

CONTRIBUTIONS to the Correspondence Departments of MECHANICAL ENGINEERING by members of The American Society of Mechanical Engineers are solicited by the Publication Committee. Contributions particularly welcomed are suggestions on Society Affairs, discussions of papers published in this journal, or brief articles of current interest to mechanical engineers.

## Shall Junior Members Vote?

TO THE EDITOR:

I have read with a great deal of interest the results of the Philadelphia Section and Mr. M. L. Cooke's plea that junior members of the Society should have the right to vote. There is just now a comparatively large class of young engineers growing up—men upon whom we are going to have to place responsibilities because of the shortage of executives—and it is interesting to note how these young men are bearing their burdens.

During the war, when it was necessary to examine the ages of men very closely, I found to my surprise that in the automotive industry if every man had been physically and otherwise able to be drafted between the ages of twenty-one and thirty-one, the automotive industry would have lost almost all of its engineers.

Now the automotive industry has certainly had a very progressive engineering personnel. The work is complicated, the mechanisms are delicate and, on the average, the engineering work involved is of a very high order and, as stated above, this has been done almost entirely by comparatively young men. There are many instances that come to my mind wherein men under thirty-one are occupied in positions of high responsibility in large firms, doing very capable and successful engineering work. During the war, we must not forget, the airplane was largely developed by young men in the draft age, as were the tank and other automotive apparatus.

I feel it desirable to recognize the fact that age should not be one of the primary requisites in deciding whether a man should be a member or not, but the man's own ability, the nature of the work he is doing, and the actual experience he has put in should be the decisive factors. There are many men of the age of twenty-five who have much greater engineering instincts and greater capacity for engineering work than men who are admitted as members simply because they are thirty-two years of age and have as well, of course, other qualifications. I, therefore, look with much interest toward any method which will allow comparatively young men who are capable of assuming responsibility, to do so.

JOHN YOUNGER.

Cleveland, Ohio.

## How Shall Engineers Organize?

TO THE EDITOR:

I wonder to what extent the current activity for the organization of a united engineers' organization is spontaneous with the membership, and whether the rank and file are really interested in it and are giving it the thought and attention that such a fundamental movement deserves.

Does the average member realize and believe in the possibilities of a general organization for increasing the opportunities for service and the recognition and emolument of the engineer?

In the general opinion, should such an organization consist:

(*a*) Of one big association of engineers of all kinds, the local branches of which would impress engineering thought and experience upon local administrations and activities, hold their members together by frequent meetings of general engineering interest, bring the engineer into prominence as a factor in the community and improve his social and material condition; the collective thought of such locals finding its expression in a national convention and its execution through national officers and committees? Or

(*b*) A federation of existing engineers' societies, local, regional and national, through local committees or councils composed of representatives of such societies as are invited to join, and a federal council composed of representatives from such local councils and from regional and national societies? Or

(*c*) Some compromise between or combination of such plans?

If a new organization, is it to be confined to professional engineers or open to all who have a legitimate interest in and connection with engineering "from," as it has been expressed, "the blueprint boy up"?

If a federation, is it to include only the professional societies or may it include those whose activities are concerned with the operative and fellowship sides of engineering and, through technical methods, with the direct betterment of the material conditions of their members?

I should like to see some expression from the membership in advance of the meeting which is to determine the form and scope which the proposed organization is to have.

F. R. LOW.

New York, N. Y.

## Professional Sections

TO THE EDITOR:

The new plan of The American Society of Mechanical Engineers for the establishment of Professional Sections meets with my hearty approval, and I am glad to learn that the idea the nucleus of which I was responsible for some years ago as a member, and later as the chairman of the Committee on Meetings, is working out in this way. It seems to be the logical sequence to our old mechanism of the sub-committees of the Committee on Meetings that sectional meetings on special topics should be arranged for.

The Society can never attain a degree of usefulness commensurate with the interests represented by its members by conducting single general meetings to be attended by everybody or nobody. This is a natural and inevitable result of the diversity of machinery with which we are concerned, and which is responsible for a corresponding difference in the nature of the problems which engineers have to solve. New machinery of each class is produced in proportion as those engineers concerned with it establish a community of interest in the problem, and the Society owes a debt to the machinery industry to provide a medium of exchange whereby these groups of engineers may have an opportunity to exchange ideas. For example, a group of engineers concerning themselves with the development of the motorship industry can derive but little help by attending a meeting where the subject under discussion is stationary steam plants, nor is there any help to be derived by engineers concerned with chemical factory machinery in attending a meeting where the subject under discussion is motor cars.

For these reasons professional sections must be organized for the discussion of the problems typical of the classes of machinery represented by the various groups of engineers who will attend the meetings of such sections. Any one group of engineers held together by a bond of common interest really consists of two groups: those concerned with the production of the machinery,

and those concerned with its proper and economic use. Together they may, by discussion, come to a real and proper appreciation of the problem; and by exchanging data materially assist in the solution of that problem. This does not mean that there will be any interference with legitimate commercial competition, but it does mean that the business represented by all will be logically and properly advanced not only for the common welfare of the machinery interests, but of the public, which is entitled to regular improvements as a mark of progress.

Unless professional sections of this kind are organized and properly conducted, the inevitable result must be the organization of separate societies; perhaps such separate societies will be organized anyway. In some cases this has happened, notably in the case of the Refrigerating Engineers and the Automotive Engineers, to cite only two examples. Other subdivisions will form unless provision is made for the development of their interests within our Society. While in special cases the interests may be so very large as to make it quite impossible properly to care for them by professional sections in our Society, I am firmly of the belief that professional sections should be maintained anyway. My reasons for this are that there are certain fundamentals underlying the design, production, and in some cases, also, the economic use of all machinery which are apt to be lost sight of in a special society; and also that there are many things produced in the development of one line of machinery or mechanical appliances which could be adopted with minor or no modifications by quite another group. If, therefore, these groups are kept quite separate, as would be the case if they met in separate societies, as the Automotive and Chemical Societies are separate from those of the Lawyers' Society, professional progress would not be as rapid as if they were to come in contact at the same time and place, where there would always be a harking back to the questions of a community of interest and basic scientific fundamentals. This means that the professional sections in the A.S.M.E. could accomplish something which separate societies could not accomplish. These professional sections will not prevent the organization of separate societies when the interests involved become large enough to justify such action, but it will prevent their premature or unwise organization. Furthermore, the maintenance of professional sections dealing with the same topics as separate societies may become, through proper coöperation, the centralizing means of establishing communities of interest among all machinery interests and the professional interests representing them.

Some of the existing separate societies which have been organized may well take this matter under serious consideration, because it is believed that some of them will do well to disband and become professional sections of the A.S.M.E. The typical cases in which this is believed to be true are those in which the separate societies are finding difficulty in securing either proper financial support or have a small and not uniformly high grade of membership, professionally speaking, and have difficulty in securing proper papers of high professional character. The interests represented by these groups can be far better served by professional sections than by struggling independently.

On the other hand, those separate organizations, such, for example, as the Society of Automotive Engineers and the Marine Engineers and Naval Architects, which have reached a high degree of society prosperity in finances, membership and number and quality of papers, enthusiasm of meetings and such matters, should welcome, and in my opinion would welcome, a parallel professional section in the A.S.M.E., and would be willing to support it as a means of coördinating related interests and fundamental professional matters, the professional section acting as a centralizing link.

As you know, I am a member of several organizations and have been a student of society affairs for quite a long time, and I am quite sure in my own mind that the professional-section idea cannot be overrated in importance, although it can of course be misused. With the Council supplying broad-minded, helpful advice and actively concerned with the problem of promoting the development of American machinery along the most effective professional lines, the professional-section idea may well be expected to produce results never yet attained, and react to the very great credit of our Society as a national institution.

CHARLES E. LUCKE.

New York, N. Y.

## Thermal Conductivity of Insulating Materials

TO THE EDITOR:

In his paper presented at the Annual Meeting and published in MECHANICAL ENGINEERING for January on page 8, Mr. T. S. Taylor has given considerable valuable information on the thermal conductivities of electrical insulating materials. Only a few heat-insulating materials are considered, however, and none of the more efficient ones.

In the case of electrical insulating materials high thermal conductivity is a desirable quality as it facilitates the dissipation of heat from electrical conductors, while obviously in the case of heat-insulating materials it is low conductivity that is desirable. Furthermore, the results are expressed in units convenient to the electrical but not to the mechanical engineer. Therefore it would seem that the paper would have been more likely to receive attention of the engineers most interested had the title been more explicit.

The units in which the results are expressed are not those ordinarily used in this country in connection with heat transmission. In order to convert gram-calories per square centimeter per centimeter thick per deg. cent. per second into B.t.u. per sq. ft. per inch thick per deg. fahr. per hour, the values must be multiplied by 2903. The values in column 5 of Table 2 are evidently gram-calories per square centimeter per centimeter thick per deg. cent. per second $\times 10^6$ and not $\times 10^4$ as stated. Therefore the equivalent conductivities in B.t.u. per sq. ft. per inch thick per deg. fahr. per hour are obtained by multiplying values in column 5 by 0.002903.

Substitution of temperature coefficients in the equation given by Mr. Taylor would give decreasing values of conductivity as temperature is increased. Conductivities of poor conductors of heat generally increase as temperatures are increased, therefore apparently the equation should read $k_t = k_0 (1 + at)$.

L. B. MCMILLAN.

New York, N. Y.

## Simplification of Venturi-Meter Calculations

TO THE EDITOR:

A paper on the Simplification of Venturi Meter Calculations, published in the April 1920 issue of MECHANICAL ENGINEERING, describes a method which its author has devised for the simplification of the calculations involved in the venturi-meter measurements of the flow of compressed air, and which reduces the work of one determination to a simple slide-rule computation requiring but a few settings. His method is based on the venturi-meter formula as given by Herbert B. Reynolds, Mem. Am. Soc. M. E. in Trans. Am. Soc. M. E., vol. 38, p. 799. In using this or any other modification of previously devised formulæ it is wise to check at least one point in the problem by a true formula, as some of the less complicated formulæ are limited in their application.

In 1898 F. G. Gasche, of the Illinois Steel Company, developed the thermodynamic formula for measuring gas and steam through the venturi meter. Nine years later E. P. Coleman, Mem. Am. Soc. M. E., in a paper entitled The Flow of Fluids in a Venturi Tube,[1] gave a formula equivalent to the author's Equations 1 and 2. The method which the author has independently worked out of handling what might be termed the most disagreeable factor of the equation is the same method which has been employed by several others. For instance, Mr. Gasche developed an elaborate series of curves and diagrams for calculating gas and steam flows

[1] Trans. Am. Soc. M. E., vol. 28, p. 483.

through venturi meters and among these were curves involving the ratios of the absolute pressures between throat and inlet, also specific heats, corresponding to the argument employed by the author in the solution of Equation 5. In 1910 Beebe and Herrick in experiments on the measurement of air through a venturi meter at the University of Wisconsin also reduced this factor to a curve.

It is probably the author's intention to confine his various conclusions to the results obtained with tests on a single small venturi meter; for a more universal application, the following exceptions should be noted:

*a* There is no difficulty commercially in making manometers to withstand working pressures exceeding 100 lb., those on the market being adapted for pressures up to 250 lb. or even higher.

*b* A friction loss of 2.5 lb. through a 1.6-in. by 0.5-in. venturi-meter tube under 100 lb. gage pressure and discharging air at the rate of 200 cu. ft. per min. is larger than would be obtained by a venturi tube of standard proportions, which would show about 1.5 lb. at this rate. It would therefore seem that the venturi tube employed in the test was of some special design, that the downstream piezometer was placed too near the outlet end, or that the loss in pressure was incorrectly indicated. Tests conducted by the Builders Iron Foundry of Providence, R. I., in 1911 on a 2-in. by 1-in. venturi-meter tube measuring air showed the friction loss to be about 1/5 of the difference in pressure between the inlet and throat. Beebe and Herrick in their tests on a 2-in. by ½-in. venturi tube also show the friction loss to be a straight-line function of the differential between inlet and throat and give the value as $F = H/5.467$, where $F$ is the friction loss and $H$ is the differential pressure. In a series of comparative tests made by W. F. Schell in July, 1914[1] between various types of meters measuring natural gas including 4-in., 10-in. and 12-in. venturi meters, it was found that "the ratio of the differential pressure to the pressure loss through the venturi meter is approximately eight to one." Messrs. Bacon and Moulson, in a comprehensive series of calibrations at the Illinois Steel Co. on venturi meters 24 in., 36 in. and 48 in. in diameter, found the drop in line pressure caused by the insertion of the meter tube to be $F = H/9$, the outlet pressure being observed about one and one-half diameters beyond the outlet end of the meter tube. Tabulating these results we have

| Size of Meter Tube Inlet and outlet diameter, in. | Friction Loss Equals differential between inlet and throat divided by |
|---|---|
| 2 | 5 |
| 4 to 12 | 8 |
| 24 to 48 | 9 |

This shows conclusively that the author's determination of friction loss was not representative.

| $\frac{A_2}{A_1}$ | $n$ | $P_1$ lb. per sq. in. | $P_2$ lb. per sq. in. | $\frac{P_2}{P_1}$ | $\left(\frac{P_2}{P_1}\right)$ |
|---|---|---|---|---|---|
| 0.2500 | 1.402 | 114.7 | 104.7 | 0.9128 | 0.1548 |
| 0.1111 | 1.402 | 114.7 | 104.7 | 0.9128 | 0.1513 |
| 0.0625 | 1.402 | 114.7 | 104.7 | 0.9128 | 0.1507 |
| 0.2500 | 1.270 | 114.7 | 104.7 | 0.9128 | 0.1326 |
| 0.2500 | 1.402 | 89.7 | 79.7 | 0.8885 | 0.1721 |
| 0.2500 | 1.402 | 64.7 | 54.7 | 0.8451 | 0.1970 |

*c* For experimental work the reduction of the author's tabular arrangement of Equation 5 to curve form, using a coarse scale, would be valuable. A wider application to venturi meters in general would involve a large family of curves due to the variations which occur in the values $A_2/A_1$, $n$, and $P_2/P_1$. For instance, for the measurement of gas each size of standard venturi meter tube has four throats, the diameters of which are approximately 3/12, 4/12, 5/12 and 6/12 of the inlet diameter. For $n$ there would be a variation from 1.402 for air to 1.135 for dry saturated steam. $P_2/P_1$ might go much below the limit of 0.90 mentioned by the author; for instance this value becomes 0.8454, assuming 50 lb. gage pressure at the inlet of a venturi meter tube connected to a mercury manometer indicating a differential of 10 lb. The wide range in the value of $f(P_2/P_1)$ for such changes in value of the terms under the radical sign is illustrated by the following table. Since this function enters as a factor in the final equation any variation in its value involves an equal variation in the calculated weight or quantity discharged through the venturi meter.

Providence, R. I. CHAS. G. RICHARDSON.

[1] Proc. Natural Gas Assn of America, vol. 8

## Industrial Training in China

TO THE EDITOR:

The writer, a member of the A.S.M.E., has been a resident of China for the past ten years and as a result of his observations is impressed with the opportunity which exists for the enlightenment of the Chinese in industrial and educational matters. He believes that a great service could be rendered in this direction by the Society or some of its members, which would benefit not only China but America as well.

At present, the Chinese have very little knowledge of what can be accomplished by the use of the best engineering processes and with modern equipment of tools and machinery. In the case of machine tools, which are at the foundation of manufacturing, a large number of those in common use are poor oriental copies of ancient European types. The Chinese believe these to be as good as any, or the best to be had, and that the work accomplished on such machines is the best that can be done. They are broad-minded and willing to learn, but can be taught the value of up-to-date methods and machinery only by actual demonstration that new methods will pay them better than those in present use. They have had no opportunity to learn that such a benefit will result from the use of modern equipment.

China also needs to be shown what good engineering schools really are and how they should be managed. In the present condition of the country it is almost inevitable that such schools should be undervalued by those in governmental power and made more a matter of political jobbery than a factor in the upbuilding of the country. Concrete examples are needed of good American technical and trade schools, controlled by Americans with American capital and equipment; for technical education has not yet come to be so highly appreciated by those in political control in China as to gain the financial support necessary for the large outlays for equipment and maintenance which such schools require.

A suggestion for help in this direction might be taken from the activities in China of such institutions as Yale, Princeton, Harvard and Oberlin. These have selected certain lines of helpful work out here and are carrying them on successfully in certain large and definitely determined sections of the country. Why should not some large, representative society or societies, like the A.S.M.E., undertake to help in this technical education?

A step in this direction has been taken by British engineering societies and firms through the establishment of Hongkong University, which is well equipped with machinery and tools contributed by numerous far-seeing manufacturers. The Germans equipped a technical school out here before the war. The French are now making a very successful effort to reach the engineering student class of young men here. There is a very energetic and well-organized society in France promoting such efforts. Special low rates of passage are offered and great friendliness shown to graduates of Chinese trade schools of what would correspond to the American high-school grade. Living wages are paid these men who, in most cases, would not otherwise be in a position to take advantage of such an opportunity.

An effort to establish an American trade and technical school is being made by Peking University, an American missionary institution controlled by broad-minded men with practical and far-sighted vision. They realize that one of the greatest needs, perhaps the greatest, for the upbuilding of China today, morally

(Continued on page 318)

# MECHANICAL ENGINEERING

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## Meeting in Memory of Andrew Carnegie

A meeting in memory of the life and work of Andrew Carnegie was held on April 25 in the United Engineering Societies Building under the joint auspices of the Authors' Club, the Trustees of the New York Public Library, the Oratorio Society, St. Andrew's Society and the United Engineering Society. The program included music by the Oratorio Society and addresses by Dr. John H. Finley and the Hon. Elihu Root. Dr. William P. Merrill of the Brick Presbyterian Church gave the invocation and tributes were read from Hon. William H. Taft, Sir Oliver J. Lodge, Viscount Bryce and Lord Morley.

## John Fritz Medal

At a meeting to be held in the Engineering Societies Building at 8.30 p. m., May 7, the John Fritz Medal for 1920 will be presented to Mr. Orville Wright, Honorary Member of The American Society of Mechanical Engineers. The speakers of the evening are to be General O. Squier, Chief Signal Officer, U. S. A., and Colonel E. A. Deeds, of Dayton, Ohio, who was prominent in the Aircraft Production Board during the war. Mr. B. B. Thayer, present chairman of the Board of Awards, will preside and Prof. Comfort A. Adams, chairman of the Engineering Division of the National Research Council, will present the award. All members of the Society are cordially invited to attend.

## American Railway Engineering Association Joins Engineering Council

The American Railway Engineering Association, whose excellent technical work in many branches of railway construction and maintenance is well known, has acepted an invitation from United Engineering Society to become a member society of Engineering Council. The Association has about 1,650 members and its headquarters are at 431 South Dearborn Street, Chicago, Illinois. Its President is Mr. Harry R. Safford, and its Secretary Mr. E. H. Fritch.

The Association has named as its representative upon Engineering Council its President, Mr. Safford, who is a member of the American Society of Civil Engineers and Engineering Institute of Canada. Mr. Safford was recently appointed Assistant to President Hale Holden, of the Chicago, Burlington and Quincy Railroad Company, the Colorado and Southern Railway Company, the Fort Worth and Denver City Railway Company, and the Wichita Valley Railway Company. He was formerly Chief Engineer of the Grand Trunk Railway, and is well known in Canada, as well as in the United States.

Six engineering organizations with a combined membership of 45,000 are now represented in Engineering Council. These are: American Society of Civil Engineers, The American Society of Mechanical Engineers, American Institute of Mining and Metallurgical Engineers, American Institute of Electrical Engineers, American Society for Testing Materials, and the American Railway Engineering Association.

## National Chamber of Commerce to Vote on Department of Public Works

The question of whether or not the Federal Government should establish a Department of Public Works has recently been submitted for a referendum vote to the 1,305 member organizations of the United States Chamber of Commerce. The result of this referendum will determine the National Chamber's attitude on this question when it comes up for Congressional action.

The questions submitted by the committee appointed by the National Chamber to make a study of this matter are as follows:

1. Shall there be established by the National Government a Department of Public Works?

2. Shall such department be established by suitable modification of the existing Department of the Interior, excluding therefrom the non-related bureaus or offices, and by the change of name of the Department of the Interior to the Department of Public Works?

3. Shall such department be created by the creation of an entirely new department?

Engineering Council, which is one of the member organizations of the National Chamber, has gone on record as favoring the adoption of the Jones-Reavis Bill (S.2232-H.R.649) now pending in Congress. This bill provides that the name of the executive department, at present designated as the Department of the Interior, be changed to the name of the Department of Public Works, and that the head thereof shall continue to be a member of the cabinet under the official designation of Secretary of Public Works. The details of this bill, which would transfer much of the work now transacted under the Department of the Interior to other departments and would also place additional bureaus under the new department, have been discussed at length in past issues of MECHANICAL ENGINEERING, notably in August, 1919, issue, p. 709, and the February, 1920, issue, p. 136.

## Putting the Technic in Technical Education

The Harvard Engineering School has adopted a new plan of instruction for the junior year of the engineering course whereby students will be given an opportunity to combine classroom work with six months of active engineering practice and industrial training.

The courses for the freshman, sophomore and senior years will remain approximately as they are now, but during the junior year the students who desire the industrial training will spend three separate periods of two months each in the outside work. The schedule will be so arranged that these students will also receive the regular amount of classroom instruction.

In general, the plan lies along the lines of the highly-developed and successful plan of industrial coöperation which was initiated by Dean Schneider at the University of Cincinnati, where it has been carried on so successfully for many years, and which also

has been applied in a modified form at the University of Pittsburgh. This plan has been modified still further to meet the different conditions and needs at Harvard, where the technical work of putting it into operation will be in charge of Mr. H. O. Drufner of the University of Cincinnati.

The plan has received the support of the Associated Industries of Massachusetts, comprising some 1400 industrial and engineering concerns, and these industries have indicated their willingness to take on as many students as the Engineering School desires to place. It is expected that the men who go into this work will be paid current wages for the periods in which they work in the plants, and that they will be able to earn sufficient money to pay their expenses during these periods, so that the experience, if not actually profitable, at least will not be a financial burden.

Professor Hector J. Hughes, chairman of the Administrative Board of the Engineering School, explains the purpose of the new plan as follows: "One of the first problems which the staff of the new Engineering School set itself to solve was to find an effective way of getting the new School and its students into closer relations with industrial and engineering work before they graduate. The need for such relations has been increasingly evident in the past few years. The object of such coördination is manifold: to stimulate interest in the classroom work; to keep the teaching staff well-informed of the needs of industry and how to train engineers to meet them; to give the students some intimate knowledge of the great problems of labor and industry which they have to meet after they graduate, and thus to anticipate to some extent the period of initiation which all students must go through and better to fit them to begin their careers; to give them an opportunity to discover how intricate and interesting the basic industries are and to what extent scientific knowledge may be used in work which is too frequently looked upon as non-technical; in other words, to find out how many kinds of careers are open to technically trained men and how wide is the opportunity for such men. Another object of the new plan is to stimulate the interest of the industries themselves in the adaptation to their special needs of education in engineering. To sum up, the object of such coördination is to give our students the chance to find themselves."

## The Outdoor Power Plant

It has been the accepted practice in engineering design that a hydroelectric power plant must be sheltered by a house. The question, however, whether there is really any need for the expensive buildings that have always been erected for housing generating equipment is of increasing importance in view of the present economic situation. This question of the practicability of the outdoor generating station is pertinently discussed by H. W. Buck in the March issue of the *General Electric Review*.

The modern, vertical-shaft, internal revolving-field generator, he argues, is essentially a waterproof structure. The vital parts of the machine are all on the inside protected by a massive casing of cast iron, and the openings in the upper spider are usually plated with steel for purposes of ventilation so that the top is protected. With slight modifications in its design, the standard vertical-shaft alternator can therefore be made proof against all stresses of weather. The waterwheels themselves naturally need no housing.

Thrust bearings are housed in heavy steel or iron casings and need little protection from weather. The various auxiliaries, including governors, connected with a hydroelectric plant can easily and advantageously be installed under the main generator floor in the various compartments naturally existing in the substructure of such a plant and there protected from the weather.

It thus appears pertinent to inquire why millions of dollars are expended to house machinery which does not need housing at all.

As an example of a scheme eliminating the expensive superstructure, Mr. Buck described the general design of the Muscle Shoals Development prepared for the War Department by Viele, Blackwell & Buck, Engineers, in August, 1918. This design comprised the outdoor installation of fifteen 20,000-kw. generating units. It was proposed to install within the generating structure itself only the water turbines, generators, exciters, governors and the various pumps. The usual iron frame of the stationary armature was to be omitted and the armature laminations and coils were to be attached to the surrounding concrete. The switchboard panels were to be located in a relatively small pilot house which would also contain the low-voltage oil switches and busbars. All of the transformers and high-tension equipment would be installed in the open, adjacent to the pilot house. In this arrangement the switchboard operators would be housed and the generator attendants also protected in the substructures. The plant auxiliaries would also be housed. All of the vital parts of the alternators could be inspected from below the machines. Only the occasional inspection of thrust bearings would have to be made in the open. In order to perform under protection from the weather the work of installation and repair on the generating units, it was planned to install a housed-in travelling gantry crane of sufficient length to cover a single unit, which would travel on rails the total length of the generator structure.

In the case of this Muscle Shoals plan the estimated saving in construction cost by omitting the superstructure was very large, amounting to over $700,000 after paying for the pilot house and gantry crane.

It is true that this Muscle Shoals scheme was designed to meet the weather conditions of Alabama, where the climate is mild, but there is no reason why it should not be possible to make an outdoor generator snow-proof as well as rain-proof. The operator would be normally housed in any case in the pilot house or between decks in the substructure, and would be required to go on deck at occasional intervals only.

## A New Development in Marine Propulsion

Five years ago the writer of this had the pleasure of listening to a paper on the Application of Electricity to Marine Transportation by William P. Donnelly, Mem. Am. Soc. M. E., presented before the Brooklyn Engineers' Club, dealing with a plan which the author had developed for the generation of electricity upon a vessel designated as the "power boat" and transmitting it by means of a flexible, waterproof cable to one or more other vessels and thereby utilizing the energy for propulsion through propelling apparatus operated by electric motor.

Mr. Donnelly at that time had designed and constructed an electrically-propelled yacht, *Dawn*, 50 ft. long and 12 ft. beam, with a 60-hp. gasoline engine, a 40-kw. electric generator and a 20-hp. motor for driving the propeller, which allowed a surplus of from 20 to 30 hp. beyond that required for driving the boat itself, to be used for the propulsion of a second boat. The yacht was designed primarily for experimental purposes, one of the features being the elaborate instrument board with fifteen dials for ammeters, voltmeters, tachometers, gages, etc.

The author pointed out that through the use of a power boat in connection with cargo vessels at sea, canal barges or pleasure boats, there would be a material saving in cargo or passenger space and expense of equipment. In the case of passenger boats it would be possible to reduce materially the fire risks, the discomfort from excessive heat in warm weather through the elimination of the steam boilers, and annoyance from excessive vibration due to the elimination of reciprocating engines. Further, it would extend the general use of electricity for refrigeration, heating, cooking, etc., adding to the convenience and cleanliness of the boats.

In an article in *Marine Engineering* for April, 1920, Mr. Donnelly publishes the sequel to his earlier paper in which he describes a second yacht, the *New Era*, completed last year and designed for pleasure purposes. The lines laid down were the same as for the *Dawn*, but with the power plant eliminated. A 20-hp. electric motor for propulsion was installed in the same manner as on the *Dawn*, below the floor of the forward cabin, thus leaving the entire cabin space free of machinery. Incidentally the yacht was made non-sinkable, following out the scheme

developed by Mr. Donnelly and tried out during the war on one of the transports. This was accomplished by placing the floor of the cabin 6 in. above the water line and filling in the vacant space below with air-tight copper tanks, and with balsa wood in the irregular parts of the hull. The electric current was received from the generating plant of the *Dawn* through a flexible cable, as described above, which ran from a reel on the bow of the *Dawn*, which was to serve as the power boat, to the stern of the *New Era*, which was to serve as the pleasure craft—in effect a floating home.

Last November a trial trip was made from New York to Schenectady, by way of the Hudson and the New York Barge Canal, the *New Era* leading and the *Dawn*, or power boat, following. The trip was successful, and demonstrated the possibilities of this method of propulsion either for pleasure or for commercial uses. It showed the great degree of comfort which could be had in touring with electric power in practically unlimited quantity so far as immediate necessities were concerned, and with the relegation to the power boat of the power plant, crew, fuel, stores and the many things which must go with one in cruising.

The broader application of electricity to marine transportation yet to be put into actual use is obvious. In place of the small yacht described we can conceive of a large power boat convoying up the Hudson one or more palatial passenger craft devoid of all the objectionable features of such boats; or similarly supplying the power for taking up freight vessels or barges. These freight carriers could be left at the dock at the terminal point and the same power boat used if necessary to bring back other vessels while the first were being unloaded. In his recent article the author points out the possibility, also, of using electrically propelled car floats conducted by a power boat floating between them and shows a schematic illustration of three electrically propelled barges moving one behind the other through a canal, and followed by a fourth barge containing the power-generating plant.

## The Measurement of Minute Motion

A little instrument recently described by an Indian scientist well-known in scientific circles in this country, Sir Jagadis Chunder Bose, and called by him the "crescograph" promises to render a service to science in some ways similar to that which has been rendered by the microscope, and particularly the ultramicroscope developed by Siedentopf and Ziegsmondy.

The instrument, full details of which have not yet reached this country, appears to comprise means sensitive enough to be influenced by movements as minute as, for example, the growth of a leaf of a plant. It magnifies these movements millions of times and projects them on a screen so that the growth of an ordinary plant can be made actually visible.

The inventor of this instrument developed it in the course of many years of investigations on the responsiveness of plants to external influences, and the crescograph has already given very important and but little suspected information on plant life.

It is obvious, however, that its usefulness is by no means limited to the particular object for which it has been developed, and one can easily see many useful fields of its application in engineering. The following few topics are mentioned simply by way of illustrating some of its possibilities and calling the attention of engineers to what may become a new and important tool of modern research.

Physics tells us that metals expand with increase of temperature and within certain limits it would appear that such expansion is proportional to increase of temperature. Whether, however, this is really so for very small ranges of temperature is by no means established and yet would be well worth knowing. The crescograph would easily show variations in the length of even a short metal bar with changes in temperature as low as 1 deg. fahr.

Another problem the crescograph could solve is what law is followed in the expansion of bodies of irregular section; for example, elliptical or streamline. The next subject on which we have practically no information at all is whether wood,—in particular, laminated wood,—is affected by changes in temperature and humidity of the ambient medium and to what extent.

We all know that a casting changes in shape within some period after it has been taken out of the mold,—a fact which often leads to important distortions and always has to be taken into consideration. We are entirely ignorant, however, as to the chronology of this change in shape and dimensions and, in fact, do not know when it begins and how it proceeds and how long it takes for it to run out with castings of various shapes. It may be hoped that a crescograph or an instrument properly developed for this purpose may one day enable us to take, let us say, a casting for a large gas engine, put on it the sensitive feelers of the instrument and within half an hour or so determine by looking on a screen in a dark room whether the casting has definitely set or is still "alive."

Numerous tests have shown that a bar of iron or steel in a magnetic field undergoes certain modifications of its dimensions, depending on the character of the metal, its location with respect to the field, strength of the field and certain other factors. In fact, attempts have been made to use this method for practical purposes in "setting" the metal.

The most interesting phenomenon, however, is the behavior of a bar of magnetic material, such as iron or steel, in an alternating magnetic field and it would have been extremely interesting to determine just how and to what extent the variations in the size and shape of the bar respond to the variations in the density of the field. There are numerous highly interesting factors here of which we are absolutely ignorant, such as the relation between the hysteresis in the magnetization of the field surrounding the bar and the hysteresis in the movements of the bar itself, factors which very materially affect practical applications of such methods.

With today's methods we are incapable of knowing what happens to the bar on every cycle of the alternations in the magnetic field and can guess at it only from the final results,—a method crude and unfruitful. With a crescograph we might be able to see the metal contract and expand on every cycle and as we can see by means of other instruments already in existence the variations in the density of the magnetic field, we should have no trouble in establishing the laws governing this highly interesting phenomenon.

It would appear, therefore, that here, as in other cases, the instrument developed for one purpose might serve to help us out in many ways for which it was never intended, and with the spirit of research abroad in the land as it is today, there is scarcely any doubt that the possibilities of the principle of the crescograph will be rapidly realized and a new world of infinitesimally small motion, which at present lies entirely beyond our ken, will be open to us.

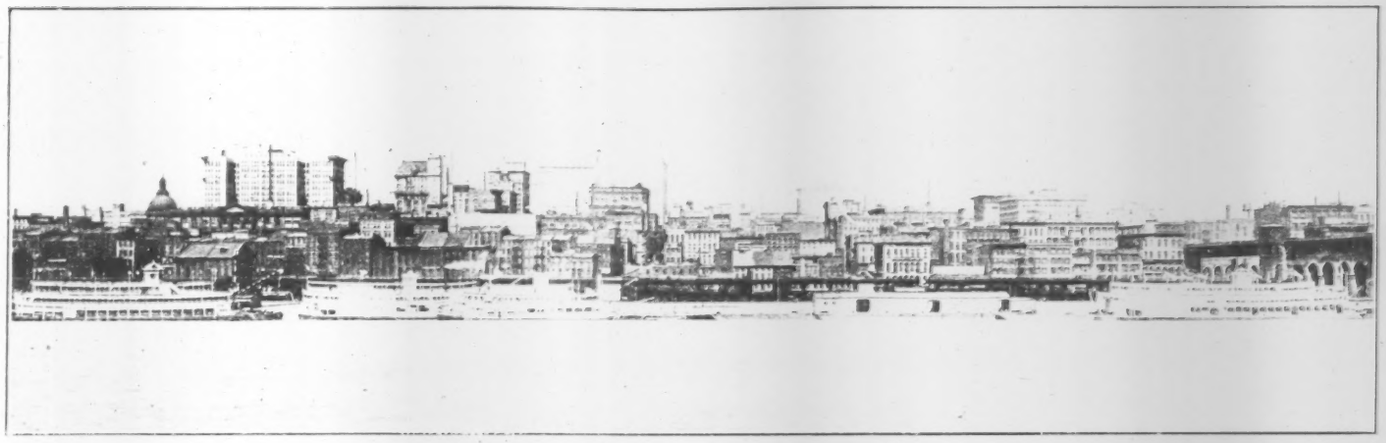
## New Engineering Periodical in Three Languages

*Engineering Progress*, the first issue of which has just been received, is a review of engineering published in Germany in three parallel editions—German, English and Spanish. It treats of German machinery and products in the various engineering fields in a semi-popular, semi-commercial manner and as far as possible in non-technical language. It is one of a very few papers devoted more particularly to the needs of the purchasers of machinery than to the students of design. In view of the present controversy as to the use of the metric and English units of measurement, it is of interest to note that although metric units are in common use in Germany, *Engineering Progress* uses the English units and does so without giving their metric equivalents.

This new periodical is published jointly by the three most prominent German engineering organizations, the Society of German Engineers; the Association of German Electrical Engineers, and the Society of German Metallurgists. The editor is Dr. C. Matschoss, well-known to many mechanical engineers in this country in connection with the trip of the members of The American Society of Mechanical Engineers to Germany not long before the war.

# A. S. M. E. Spring Meeting at St. Louis

## Headquarters, Hotel Statler—Dates, May 24-27—Excursions to Keokuk and Tulsa



St. Louis River Front

EN route to the meeting, members will have an opportunity to visit the Keokuk Hydraulic Power Development. Special cars or a train will be arranged to bring the members together on Sunday, May 23, at Keokuk. The opportunity to see this remarkable plant and development is one that every engineer should grasp.

### The Technical Sessions

The papers to be presented at the Meeting Sessions have been grouped under the headings of Appraisal and Valuation, Aeronautics, Foundry, Scientific, and Power and Combustion. A session with papers presented by St. Louis members covering miscellaneous subjects has also been arranged.

The Appraisal and Valuation Session with which the meeting will be opened on Monday afternoon is a continuation of a session on the same subject held at the 1919 Annual Meeting, where such great interest was shown that time did not permit full discussion. This session at the Spring Meeting will therefore give the members an opportunity to complete the discussion and consider the new papers presented. In this day of inflation and profiteering, the stand of the engineering profession on questions of appraisal and valuation is of extreme importance. This is rapidly being realized and the subjects to be discussed will make this session one of great value to every engineer.

Tuesday morning is given over to a session of special interest to St. Louis engineers and to a consideration of the Elevator Code. The St. Louis Session will discuss the housing problem, vital to every community today, and the river-transportation situation, upon which the development of St. Louis so largely depends. Papers will also be given by St. Louis engineers on a new form of stoker and on the subject of screw threads.

The Aeronautic Session, to be held simultaneously with the Foundry Session, comes Wednesday morning. The authorities at McCook Field have revealed a method by which the effect of unknowns may be reduced in the design of propellers. This method is set forth most interestingly in the paper by Messrs. Caldwell and Fales, the presentation of which will be aided by

St. Louis Bridges

Free Bridge

Eads Bridge

motion pictures of a phenomenon seldom exhibited—air in motion. The eminent French engineer, A. Rateau, who so ably assisted his country in airplane development during the war, is contributing at this session a paper of basic theoretical value to the airplane designer. Further, the work of the Bureau of Standards in the Design, Construction and Inspection of Aeronautic Instruments is well set forth in the paper by M. D. Hersey. The fourth paper for the meeting is of a research nature, covering the Flow of Air through Small Tubes.

The Foundry Session will contribute valuable data to the machinery designer. The various characteristics and limitations of the different types of metal castings will be given by men thoroughly familiar with their subjects.

Thursday morning is given over to the Scientific Session and the Power and Combustion Session. The Scientific Session is held jointly with the American Society of Refrigerating Engineers and the American Society of Heating and Ventilating Engineers, and a paper on the Thermal Conductivity of Heat Insulators is to be contributed by M. S. Van Dusen for the first-named society. The record of a research made for the Engineering Foundation will be presented in a paper by Clemens Herschel which gives the results obtained in his development of a weir for open-channel measurement of the flow of water. The other papers to be considered at this session relate to venturimeter calculations and to the dissipation of heat by various surfaces.

The Power and Combustion Session will consist of papers on the burning of pulverized coal at high altitudes, on the description of a new development in locomotive feedwater heaters, on a method of separating dissolved gases from boiler feedwater, and on the efficient use of natural gas in domestic service.

A complete list of the papers is given here so that the membership may order the copies they desire for consideration before the meeting. The coupon facing page 263 of this issue should be used in ordering advance papers.

### Papers to Be Presented at Meeting

Appraisal and Valuation Methods, David H. Ray
Fundamental Principles of Rational Valuation, James Rowland Bibbins
Data on the Cost of Organizing and Financing a Public-Utility Project, by the late F. B. H. Paine (contributed by Dean M. E. Cooley)
The Construction Period, H. C. Anderson
Price Levels and Value, Cecil Elmes
The Housing Problem, Nelson Cunliff
Industrial Housing, Leslie H. Allen (Springfield, Mass)
River Barges and Terminals, Wm. S. Mitchell
Mississippi Valley River Transportation Activities, E. W. Schadek
Burning Eastern Coals Successfully on a Conveyor Feed Type Stoker, L. R. Stowe
Tight-Fitting Threads for Bolts and Nuts, C. B. Lord
Physical Basis of Propeller Design, F. W. Caldwell and E. N. Fales (illustrated by moving pictures)
Analytical Theory of Airplanes in Rectilinear Flight and Calculation of Maximum Cruising Radius, A. Rateau, Hon. Mem. Am. Soc. M. E.
Aeronautic Instruments—General Principles of Construction, Mayo D. Hersey
Flow of Air Through Small Tubes, T. S. Taylor
Weir for Gaging the Flow of Water in Open Channels, Clemens Herschel
Simplification of Venturi-Meter Calculations, Glenn B. Warren
Dissipation of Heat by Various Surfaces, T. S. Taylor
Pulverized Coal in Metallurgical Furnaces at High Altitudes, Otis L. McIntyre
Efficiency of Natural Gas Used in Domestic Service, Robert F. Earhart
A Method for Separation of Dissolved Gases from Water and Some of Its Uses, J. R. McDermet
Locomotive Feedwater Heating, Thos. C. McBride
Gray-Iron Castings, Richard Moldenke
Malleable Castings, Enrique Touceda
Steel Castings, John H. Hall
Aluminum Castings, Zay Jeffries
Die Castings, Charles Pack
Brass and Bronze Castings, C. H. Bierbaum
Elevator Code, (Committee Report)

### Elevator Code and Rules for Air Tanks and Pressure Vessels

The Elevator Code will be presented for public discussion at a session to be held Tuesday morning. This code is the result of several years' work on the part of the Committee on the Protection of Industrial Workers of The American Society of Mechanical Engineers, assisted by the U. S. Bureau of Standards, elevator manufacturers' associations, casualty and fire insurance companies and related engineering societies and elevator specialty manufacturers. The code covers the construction, operation and maintenance of elevators, dumbwaiters and escalators.

The Boiler Code Committee will present for preliminary open-meeting discussion the rules for the construction of air tanks and pressure vessels, published in the January, 1920, issue of MECHANICAL ENGINEERING. This presentation will be made Wednesday morning simultaneously with the Aeronautics and Foundry Session.

### Entertainment

A series of entertainments and excursions have been laid out to insure a very agreeable passing of time and an opportunity to see the points of greatest interest in St. Louis. The excursions include trips to the plants of the Commonwealth Steel Company, Busch-Sulzer Diesel Engine Company, Heine Safety Boiler Company and the large power and gas plants, as well as to the parks and botanical gardens. One afternoon will be given over to a boat ride up the river to the Chain of Rocks. The evening entertainments will be enhanced by addresses to be given by Lt.-Col. H. W. Miller and E. R. Jackson. Lt.-Col. Miller will tell of the remarkable Belgian coast defences erected by the Germans after their occupation. These fortifications rivaled Heligoland in impregnability and remained intact under frequent British bombardment during the war. Mr. Jackson's talk will cover the Motor Convoy from Washington, D. C., to San Francisco in the summer of 1919, which he accompanied as Ordnance observer. A joint entertainment with the other societies holding meetings in St. Louis and with all of the local engineers will be held in the mammoth Municipal Open Air Theater in Forest Park on Wednesday evening.

### Tulsa Trip and Meeting

Those going to Tulsa will leave St. Louis on Thursday evening, May 27, arriving in Tulsa in the morning. The Mid-Continent Section of the Society has planned a fine program of trips and meeting sessions to be held jointly with the Oklahoma Section of the American Chemical Society. The trips will include an inspection of the large oil refineries and a visit to the oil fields where wells in various stages of development will be seen. The following papers will be presented at the Tulsa meeting:

The Preparation of Motor Gasoline from Heavier Hydrocarbons, Prof. Fred W. Padgett, the University of Oklahoma
The Influence of Tidal Forces on a Flowing Oil Well, J. E. Stillwell, Bartlesville, Okla.
The Manufacture of Synthetic Gasoline from Crude Mineral Oils by the Aid of Hydrosulphates, F. C. Thiele, Oklahoma City, Okla.
Municipal Water Works, T. R. Hollway, Tulsa, Okla.
Meta-Nitrophenyl Ethers, Dr. Hilton I. Jones, of Oklahoma A. and M. College
What Is Gasoline; Light Petroleum Products Defined, D. E. Foster, Tulsa, Okla.
Mid-Continent Gasoline, Dr. Charles K. Francis, Tulsa, Okla.

Dean M. E. Cooley of the University of Michigan will also address the meeting.

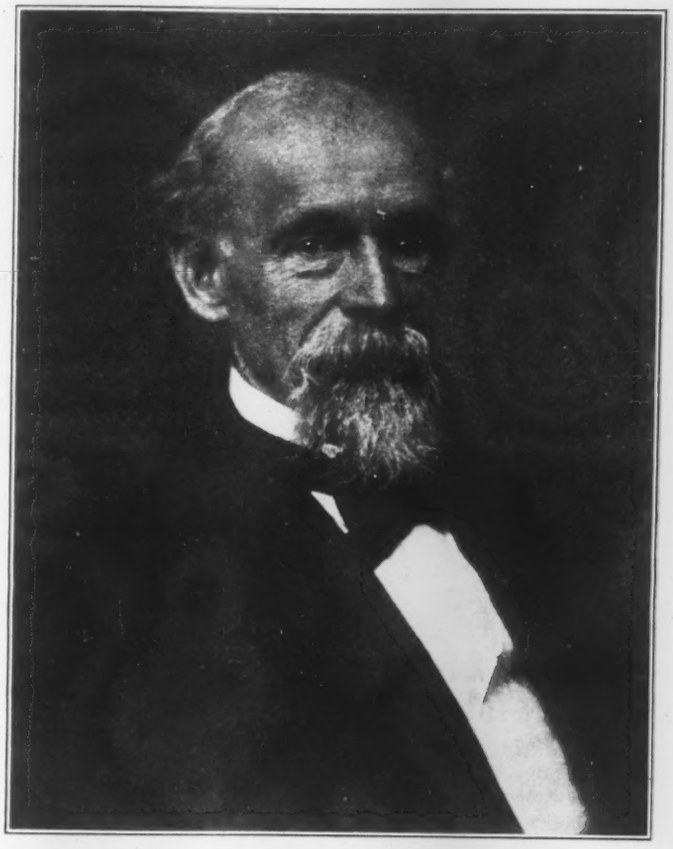
### Reservations and Excursion Arrangements

The St. Louis headquarters of the meeting will be the Hotel Statler, where the meeting sessions will be held. Reservations at the Statler should be made at once by communicating directly with the hotel. It is requested that all those who have any intention of attending the meeting will fill out the coupon facing page 263 of this issue and send it in at once.

# John Alfred Brashear

ENDING a long and active career of notable achievement, Dr. John A. Brashear, famed throughout the world as a scientist and maker of precise astronomical instruments, and known to a multitude of devoted friends as "Uncle John," died at his home in Pittsburgh on April 8, in his eightieth year.

During his later years he was the recipient of several honorary degrees, but when asked at one time what degree he would prefer, he replied, "Doctor of Humanity," which fitly expresses the crowning characteristic of his life, evident in all his relations with his fellow-men. It would be difficult to recall the name of any person in recent years who has received the outward expression of real devotion from so many men, women and children, of all stations of life and of all nationalities, as did John A. Brashear. On several anniversaries he received testimonials of appreciation and respect, literally by the thousand, and it is a source of gratification that he could have lived to receive such abundant recognition of the value attached to a life of service.



JOHN ALFRED BRASHEAR

He was born at Brownsville, Pa., November 24, 1840, attended the Brownsville common school, learned pattern-making, and at the age of 22 was established, apparently for life, as a millwright in a Pittsburgh rolling mill. He remained in millwork for 20 years, after which he engaged in his life work of astronomical and physical instrument making.

From his earliest boyhood the study of astronomy had been his hobby. A traveling astronomer exhibiting the wonders of the heavens to passersby at five cents a look gave to John Brashear, then a lad of seven, his first glimpse of the wonders of the heavens. This made a deep impression on his young mind and he began to dream and study about the stars. He longed for a telescope of his own, and when he became married early in his industrial life he and his wife set out to make one. They fitted a workshop with a small engine and lathe at their humble home on the south side of the city where they made the tubes and ground the lenses, often working until midnight in absorbed joy in the work after a long, hard day at the mill and household tasks. Their first glass took three years to grind. Dissatisfied with its limitations, they set to work on a larger one only to have it break in the silvering process after two years of patient grinding and correcting.

The next night Brashear returned from the mill completely discouraged. His wife was not in the kitchen, so he wandered out into the workshop, where he found a fire under the boiler, steam up and a fresh piece of glass in the lathe. "We'll make a new one," his wife said, and they did. This proved to be the turning point in Brashear's life and was the beginning of his really great work in the field of science. Through the interest which he attracted from Langley, of flying-machine fame, then head of the Allegheny Observatory, he was enabled to move to Allegheny and set up a shop for lens grinding,—the beginning of the firm of John A. Brashear Company, Ltd., known today wherever astronomical instruments are used. Here have been made many of the most important optical parts in the world. It has been the policy of the firm to have no patents and no secrets. Whatever it accomplished it has given freely to the world. His son-in-law, Mr. James B. McDowell, joined him in the work and to him Dr. Brashear gave a large share of credit for the success of the undertaking.

Of the products of the Brashear Company reference should be made to the following:

A 72-in. parabolic mirror, Dominion Observatory, Victoria, Canada. The illustration on the next page shows Dr. Brashear at work on this glass in his workshop.

Two 37-in. parabolic mirrors for Lick Observatory, Mt. Hamilton, Calif., and University of Michigan, Ann Arbor, Mich.; and one 30-in. parabolic mirror for Allegheny Observatory, Pittsburgh, Pa.

Several plain and parabolic mirrors and object glasses ranging from 18 in. to 30 in. in diameter for Yale University, New Haven, Conn.; Allegheny Observatory, Pittsburgh, Pa.; Swarthmore College, Swarthmore, Pa.; Chabot Observatory, Oakland, Calif.; Dominion Observatory, Victoria, Canada; and University of Pennsylvania, Philadelphia, Pa.

Some twenty-five object glasses, ranging from 9 in. to 18 in. in diameter, for various other observatories throughout the world.

A 16-in. photographic doublet for the Königstahl Observatory, Heidelberg, Germany, and a 10-in. photographic doublet for Bruce Telescope, Yerkes Observatory, Williams Bay, Wis.

Perhaps his most important achievement was in connection with the design and development of the spectroscope for astronomical uses. Many of the spectroscopes in the principal observatories in the world have been made in the Brashear workshop, including that for the 38-in. telescope of the Lick Observatory. The excellence of the work done by Professor Keeler at this observatory is freely attributed to Dr. Brashear's skill and genius.

In 1884 Dr. Brashear was commissioned by Professor Rowland of Johns Hopkins University to make the speculum metal plates for his diffraction gratings. Mr. Ambrose Swasey, in his presidential address before the A. S. M. E. in 1904, referred to the extraordinary accuracy of these plates and of others made by Dr. Brashear for Professor Michelson in connection with the determining of the standards of length. Mr. Swasey said:

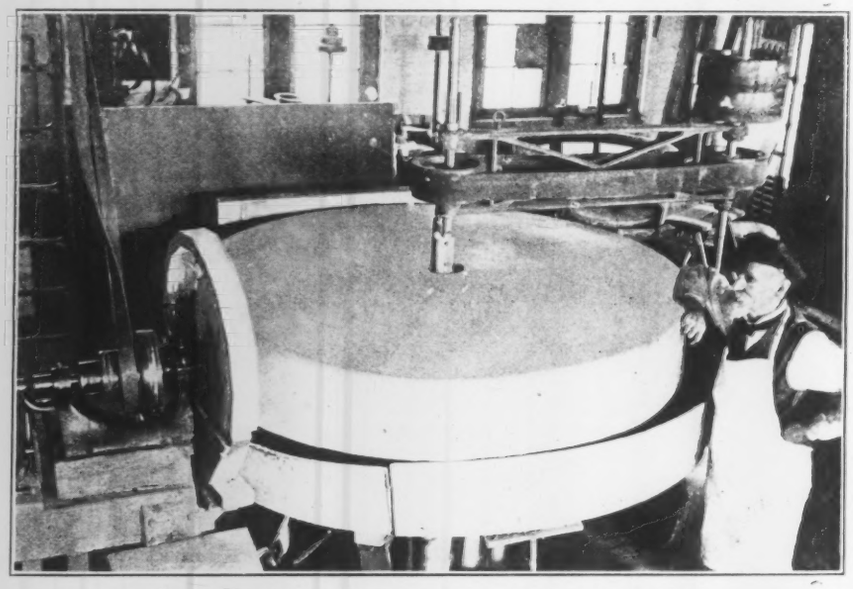
> The Rowland engine was made especially for ruling diffraction gratings of speculum metal, and with it a metal surface has been ruled with 160,000 lines, there being about 29,000 to the inch, and as many as 43,000 lines to the inch have been ruled.
>
> The gratings mostly used have from 14,000 to 20,000 lines to the inch, and with such exactness is the cutting tool moved by the screw that the greatest error in the ruling does not exceed one millionth of an inch.
>
> The production of these gratings, which has enabled the physicist in his study of the spectrum to enter fields of research before unknown, has not only called for the highest degree of perfection ever

attained in the spacing of linear distances, but it has also called for a refinement most difficult in the optical surfaces upon which the lines are ruled. To Mr. Brashear was given the problem of producing such surfaces, and notwithstanding the many difficulties encountered in working and refining the speculum metal plates, he has made many hundred plates with surfaces either flat or curved with an error not to exceed one-tenth of a wave length of light, or one four-hundred thousandth of an inch.

As the established standards of length, which are the yard of Great Britain and the meter of France, are made of metal, and liable to destruction or damage, Professor Michelson conceived the idea of determining the lengths of these standards in wave lengths of light, which would be a basis of value unalterable and indestructible.

For the purpose of carrying out these experiments, the interferometer was constructed, an instrument which required the highest order of workmanship and the greatest skill of the *optician*. Again Mr. Brashear proved to be equal to the occasion, and made for the instrument a series of refracting plates, the surfaces of which were flat within one twentieth of a wave length of light, with sides parallel within one second. This was the most difficult work ever attempted in the refinement of optical surfaces.

No event in Dr. Brashear's life gave him greater satisfaction, nor elicited from him greater enthusiasm than the completion of the 72-in. glass for the Dominion Observatory, and its safe arrival at Victoria. The disk of glass was cast in Belgium and weighed when completed for shipment from Pittsburgh 2¼ tons. The final grinding and polishing was done by hand in the basement of the Brashear workshop where temperature conditions could be kept constant and where the great tube with its double walls was located for making the final tests. The correcting of the surface had to be done by hand by local polishing. After working on the glass for a few hours it had to be lifted to the testing tube where it remained for 10 hours to attain uniform temperature. When the glass finally arrived at Victoria in its special car Dr. Brashear wrote: "The glass reached its destination in less than six days after I bid it good-bye on the car in Pittsburgh, a trip of 2200 miles. You bet Uncle John and his son-in-law and some others are happy over this news, after three years and eight months." The Dominion Observatory was dedicated on June 11, 1918.



DR. BRASHEAR AT WORK ON THE 72-IN. DISK FOR THE CANADIAN REFLECTING TELESCOPE

Dr. Brashear's scientific work brought recognition and about the time of his removal to Allegheny he was given an appointment in the University of Western Pennsylvania of which the Allegheny Observatory was a department. From 1898 to 1900 he was acting director of the Allegheny Observatory and raised $300,000 for the building and equipment of a new observatory in Riverview Park. He always kept in touch with the development of this observatory, and through his efforts one department has been put in every possible way at the disposal of the public, as well as for astronomical and astrophysical research.

For twenty years past Dr. Brashear has been a trustee of the Carnegie Institute, for fifteen years of the Carnegie Institute of Technology and for twenty years of the University of Pittsburgh, of which latter he has also served as chancellor. Several years ago a friend placed in his hands an endowment fund of $250,000 to be used for the advancement of teachers and teaching in the public schools, as a result of which to date over seven hundred teachers have been sent to different parts of the country for rest and study, bringing back with them new ideas and greater enthusiasm.

Dr. Brashear was elected to membership in The American Society of Mechanical Engineers in 1891 and was made an honorary member in 1908. He was a manager of the Society from 1899 to 1902. In 1911 he was elected one of the Society's representatives on the John Fritz Medal Board to serve for four years. He was president of the Society for the year 1915, during which time he twice toured the country, visiting the sections and speaking before many engineering and other organizations. His magnetic personality made him always in demand as a speaker. Later he addressed large audiences of the Society on Photography of the Stars and once on The Science of the Beautiful in Commonplace Things.

He was a fellow of the American Association for the Advancement of Science and the Royal Astronomical Society of Great Britain; he was a past-president of the Engineering Society of Western Pennsylvania and the Pittsburgh Academy of Arts and Sciences; he was a member of the British Astronomical Association, the Société Astronomique de France, Société de Belgique, the American Philosophical Society, the Astrophysical Society of America, the Washington Academy of Sciences, the National Geographic Society, and an honorary member of the Royal Astronomical Society of Canada.

He was honored with the degree of LL.D. by Washington and Jefferson College, by Wooster University and by the University of Pittsburgh, and with the degree of Sc.D. by Princeton University and the Western University of Pennsylvania; also with the degree of Doctor of Engineering by Stevens Institute of Technology.

A few years ago he was voted Pennsylvania's foremost citizen by a committee of prominent men appointed by the governor of the state. Governor Brumbaugh had been asked by the officials of the Panama-Pacific Exposition to name the most distinguished citizen of Pennsylvania. Having consulted men of prominence throughout the state, the Governor unhesitatingly named John Brashear. When word of this honor was brought to "Uncle John," he was at work in his laboratory and his only comment was: "I guess you're joking." Then he went on with his work.

Dr. Brashear's seventy-fifth birthday was celebrated with a dinner that will long be remembered in Pittsburgh. Alexander Graham Bell, Charles M. Schwab, Henry Clay Frick, Rear-Admiral Robert E. Peary and many other men of high achievement joined with Uncle John's neighbors to pay him homage. One thousand people sat down at dinner and the table was piled high with telegrams of congratulation—from the president of the United States, from men of science all over the world and from thousands of his less-famous but as well-loved neighbors. That night Dr. Brashear's friends made up a purse of fifty thousand dollars, the interest of the fund to go to him as long as he lived and after that "to carry on, but not to take the place of," the work he had begun.

Scarcely less notable was a public reception tended him at Pittsburgh on the eve of his 76th birthday and of his departure for an extended trip to the Orient, with Messrs. Ambrose Swasey

and John R. Freeman, Past-Presidents A. S. M. E. Concerning this, the following extract from a letter written at the time by his secretary, Miss Martha C. Hoyt, gives a just estimate of the affection in which he was held by the people of his own city.

It was a truly wonderful sight, such as Pittsburgh will probably never see again. In the receiving line were the Jew and the Christian, Protestant and Catholic, well-known public men and private citizens, the rich and the poor. There were even people whom the doctor has rescued from privation. In the line which came to greet him were the most prominent educators, social and financial leaders, down to the dirty little newsboy with his papers under his arm, who conducted himself during his progress down the receiving line with as much dignity as the more experienced members of society. There was a deaf and dumb man who knew him when a young man and brought his congratulations and best wishes written on a paper so he would not take too much of Dr. Brashear's time presenting them, and an Italian laborer who was attending night school in the neighborhood and came running in to say what his teacher had taught him for the occasion: "I wish you many happy returns of the day." He was radiant with his success at being understood. There were delegations from the Carnegie Technical Schools, the University of Pittsburgh, the School for the Blind, the Newsboys Home, and the Loendi Club, a group of colored men in whom he has been interested and who have had their share of his loving service.

Among the many benevolent acts which were typical of the life of Dr. Brashear was the founding three years ago of the Brashear Settlement Association which has its headquarters in the old Brashear home, where the doctor spent his younger years. He suggested that the house should be called "Inspiration," for the humble old-fashioned structure with the rude shop in the rear would point out to these lads that from humble beginnings one may rise to greatness through hard work.

Upon the last celebration of the anniversary of his birth in November, at his request, money which would have been used by his numerous friends to purchase gifts for him was given to the Brashear Settlement to enable it to further the work which it had instituted. It was Dr. Brashear's wish that the work should live after his death, and acting upon this the officers of the Association will endeavor to make it a permanent tribute to his name. On this same anniversary a "birthday shower" of postal cards was arranged by the officers of the Brashear Settlement House and it was planned and carried out for thirty thousand Pittsburghers to send cards of greeting to Uncle John. At this time Dr. Brashear was confined to his home by illness.

Memorial Hall, Pittsburgh, was the scene of Dr. Brashear's funeral services, which were simple and carried out in accordance with his wishes expressed shortly before his death. Thousands from all walks of life were present to show the love they had for "Uncle John." Not only was the great hall filled, with hundreds standing, but many hundreds more for whom there was no room lingered outside. The ashes of Dr. Brashear, together with those of his wife, Phoebe Stewart, who died a few years ago, will rest in the base of the great telescope erected in Allegheny Observatory. The inscription, written by Dr. Brashear, reads, "We have loved the stars too fondly to be fearful of the night."

# Government Activities in Engineering

*Notes Contributed by The National Service Department of Engineering Council*[1]

## Congress To Study Reorganization of Federal Executive Departments

When the Public Works plan was set in motion by the introduction of the Jones-Reavis Bill in the Senate and House, comparatively little attention was paid to it by the legislators on Capitol Hill. As the importance of this measure was impressed upon them through their constituency back home, through personal calls from prominent engineers, and through the definite message that was the result of the hearings before Senator Smoot's Committee on Public Lands, there was a general awakening as to the existing conditions throughout the executive departments. With this awakening came a desire for more knowledge as to the exact conditions to which the enormous wastes in Government operations could be traced.

And under existing demand for a material cut in Government expenditures, there were produced two definite plans, one in the House and one in the Senate, proposing to investigate all the activities of the executive branches of the Federal Government with a view to their reorganization on a business basis. This was substantially the job which the engineers had taken upon themselves with regard to the engineering functions of the Government.

The most recent proposed legislation on this subject is the Senate Joint Resolution No. 191, introduced by Senator Smoot. It proposes a "joint committee on reorganization" to consist of three members from the Senate and three members from the House. This joint committee is to make a survey of the administrative services of the Government to secure pertinent information as to their distribution among the several Government departments, including their overlapping and duplication of authority, with a view to redistribution of activities under proper correlation. The regrouping under each executive department is to be such that only services having close working relation with each other administering directly to the primary purpose of that department are to be included therein.

The committee is to report its findings, prepare and submit bills or resolutions for the coördination of Government functions and their most efficient and economic conduct, and will employ experts in this kind of work, expenses to be equally divided between the Senate and House.

The wording of this resolution is obviously entirely in line with the plan for a National Department of Public Works, and needless to say it has the sanction and active support of the National Public Works Department Association.

## Mail Tunnel Systems for Large Cities

When the Senate and House conferrees agreed on the Post Office appropriation bill, it contained a provision for a commission, which is to study among other things, the advisability of establishing a system of tunnels to handle mail in congested centers—especially in New York City.

The commission is to consist of a chairman and four members of the Committee on the Post Office and Post Roads from both the Senate and the House and a postal expert appointed by the Postmaster-General. This commission is to have authority to appoint an advisory council of seven to be composed of those having special knowledge of the work in hand—preferably representatives of commercial organizations, and engineers who are acquainted with existing conditions and requirements. Further, the commission is authorized to employ such engineers and special experts as it is deemed necessary to assist in its investigation.

The appointment of the advisory council to this commission is in line with the recommendations that Engineering Council has made to the Post Office Committee of Congress. It is especially fitting that this legislation should carry special provision for the use of engineering opinions in the accomplishment of a joint congressional committee's work.

[1] Engineering Council is an organization of national technical societies created to consider matters of common concern to engineers as well as those of public welfare in which the profession is interested. The headquarters of Engineering Council are located in the Engineering Societies Building, 29 West 39th Street, New York City. The Council also maintains a Washington office with M. O. Leighton, chairman of the National Service Department, in charge. This office is in the McLachlen Building, 10th and G Streets, Washington, D. C. The officers of Engineering Council are: J. Parke Channing, *Chairman*; Alfred D. Flinn, *Secretary*.

## Road Legislation

It will be recalled that last year's Post Office appropriation bill carried a rider appropriating $200,000,000 of the Federal funds for road construction throughout the several states. This year the bill became law without any provision for highway legislation, solely because it had not been seriously urged that increased appropriations or further legislation extending Federal aid should be included.

When the conference report was finally accepted on the floor of the Senate, Senator Townsend, the sponsor of the bill to establish a national highway system under a highway commission, gave notice that he intended to proceed with hearings on this bill and would soon be prepared to present to Congress more concrete information for an improved highway policy. The need of investigation on this subject was emphasized because it was contended that the continuity of good roads is necessary for general welfare in time of railroad strikes and when for other reasons the rail transportation facilities do not meet the needs of the public.

Some discontent exists among legislators because they are not pleased with the way that Federal money is being expended in highway construction. This is largely due to conditions in the states where the Federal aid money is divided among counties in the same way the Government apportions it to the state, that is, according to population, territory, and road mileage. Short stretches of good roads are the result instead of complete through highways built for permaneney. Senator Townsend said, "I maintain that the present methods of expending Federal aid funds are inexcusable."

Senator Townsend urges connecting road systems between the states and a provision for permanent maintenance. He seeks a national system, built and maintained by the Federal Government for the good of the whole country and built on such a basis that they will inspire the states to build good road systems connecting the Federal roads. The Townsend bill provides that the national system of highways be composed of two roads in each state, one running east and west and one running north and south.

The Post Office appropriation bill carried a provision whereby tractors may be loaned by the War Department to the states for use in highway construction. When the conferees finally agreed to this provision the Secretary of War was vested with authority to use his discretion in loaning such tractors as could be spared for road construction work. All expenses for repairs and upkeep as well as loading and transportation charges are to be paid by the state.

The Military Affairs Committee has also favorably reported the Reavis Bill, H. R. 13329. This provides for transfer of additional machinery and equipment to the Bureau of Public Roads for use in highway construction, and will permit of the use of mobile machine shops and other similar army equipment. According to reports recently submitted by the Bureau of Roads, this equipment will be very acceptable and will be immediately put to good use.

## Important Flood Legislation

The Minnesota River and the Big Stone Lake, which are on the boundary between Minnesota and South Dakota, are proposed for flood protection in a bill which has just passed both House and Senate. This legislation will protect property worth millions of dollars when it is enacted into law and put into effect. Minnesota flood-control work has been delayed up to the present time because that state is forbidden by its constitution to spend funds for such internal improvement. It is proposed to use the Big Stone Lake as a reservoir to hold back the flood waters, this being accomplished by the construction of a dam at the foot of the lake. The entire cost of improvement is to be borne by those benefited according to provisions of the bill. The project has the sanction of prominent engineers and the approval of the Engineers Corps of the War Department.

## Reclassification and Compensation in the Government Service

What has been known as the Keating Commission on Reclassification and Compensation of Federal Employees has been at work for fifteen months investigating every branch of the personnel in the Government Service, with special reference to compensation. On several occasions the national engineering societies have been called on for information which they were able to compile and for general advice on technical service. One of the largest committees formed for this purpose was able to advise as to existing salaries in the technical-commercial field.

The Commission found in its investigations the same kind of troubles that appear to be chronic in our Government. For instance, pay for the same positions requiring the same qualifications show wide variations from department to department, and in many cases within the same department. This was especially in the war expanded departments. The report shows that the Government has no standard guide in fixing salaries appropriate to the character and importance of the work, so that there is little or no means of rewarding special training or marked ability. In many cases there is no uniform system of promotions nor reward for long service. These factors were shown to lead to many ambiguities in appropriations for Government service and to a serious growing discontent of Government employees, especially technical employees. Wide variation was everywhere apparent from accepted commercial practice.

Detailed recommendations for first classifying all Government employees and then obtaining a standard compensation in these various classes covered over 200 pages of the report, while nearly a thousand additional pages were used in what appears to be a vast dictionary of Government positions. This report covers every kind of technical position in the Government.

It is contemplated that this report will form the basis for a bill proposing at least some helpful changes in Government positions but it is hard to tell when such proposed legislation will receive attention before either the House or Senate.

## Classification of Subordinate Railroad Engineers

The Interstate Commerce Commission has held lengthy hearings on the classification of engineer assistants in the railroad employ, and as a result has issued regulations classifying subordinate officials as provided in the Transportation Act. These engineers are grouped into a class as "Engineers of Mechanics." This class includes Civil Engineers, inferior in rank to Engineers of Maintenance-of-Way, Chief Engineers or Division Engineers. It includes draftsmen, engineers on maintenance-of-way work, and other engineers of mechanics, who are not vested with authority to employ, discipline or dismiss subordinates.

Representatives of the American Association of Engineers, whose membership includes many engineers in this class, presented arguments in favor of a separate grouping for subordinate technical engineers. It was shown that twenty thousand technical engineers in the employ of the railroads would be included in such classification, whereas only five per cent of that number are engineers that come within the category of executives. No other class of railroad employees have a more trusted relationship with their companies than do the subordinate engineers, assistant engineers, architects, rodmen, chairmen, and draftsmen. Because of the fact that this class of engineers have previously had no classification they have received practically no consideration from the railroads in the point of increases in salary, promotion, schedules, etc. For the same reason, also, it has been hard for engineering organizations representing them to obtain improved conditions.

It will be recalled that the Engineering Council went before the old Board of Wages and Working Conditions under the Railroad Administration to assist in getting a classification and increased compensation for the men who have now been classed "Engineers of Mechanics." Some good was accomplished but conclusive results could not be obtained because this group of engineers were not then known as a unit on the railroads.

# NEWS OF THE ENGINEERING SOCIETIES

Meetings of the Industrial Relations Association of America, the Society of Industrial Engineers and the American Railway Engineering Association

## Industrial Relations Meeting in Chicago

The Industrial Relations Association of America, formerly the National Association of Employment Managers, will hold its Second Annual Convention in the Auditorium Theater, Chicago, from May 19 to 21. The program will cover the various phases of employment and industrial relations work. Two sessions will be held daily on broad subjects such as Man and Industry, Community Conditions Affecting Labor Stability, The Foreman of the Present and Future, Organized Labor in Industry, and Incentives and Production. Subject Luncheons and Section Dinners have been arranged for the discussion of the details of the work. Some of the subjects to be discussed at these affairs are Americanization, Shop Committees, Insurance Plans, Developing Plant Spirit, Radicalism, and Financial and Non-financial Incentives. The speakers will be manufacturing executives and labor leaders of prominence, while the chairmen of the sessions will be employment managers of experience and ability.

## Society of Industrial Engineers

The practical application of the principles of industrial engineering was the keynote of the spring meeting of the Society of Industrial Engineers held at the Bellevue-Stratford Hotel, Philadelphia, on March 24-26. The feature of the meeting was a paper by C. E. Knoeppel, president of the New York industrial-engineering firm bearing his name. He chose as his subject, The Most Effective Type of Industrial Organization, and used as an illustration of the ideal, the human body. Everywhere in the human body it is found that while each organ performs some definite function, the coöperation of all is necessary to the life of the person. While two or more organs perform totally distinct functions, they coöperate for some major or compound function in which their individual functions are completely merged.

Mr. Knoeppel outlined the managing organization of the human body as follows: The chief executive—the cerebrum—exercises judgment, reason, cognition, and volition; the first assistant—the cerebellum—coördinates and harmonizes the voluntary organs and thus guides the performance of the organization; the second assistant—the medulla oblongata—coördinates and harmonizes the work of the involuntary organs in order that the proper service may be secured; the intelligence, formulative and standardization bureau—the cranial nerves—control and link up the action and routine division with the coördinating division.

A better example of organized control cannot be found anywhere in the whole wide world, declared Mr. Knoeppel; its component parts are of a finer kind than we shall ever approximate, and the functions and their relations are coördinated more smoothly than we shall ever be able to arrange human relations. We can, however, pattern our industrial organizations after this perfect model with the full expectation of securing both economy in the expenditure of energy and efficiency in the attainment of results.

Dexter S. Kimball, dean of the college of engineering, Cornell University, spoke on How Industry Can Assist the Educator, and pleaded for greater coöperation from the industries with the student and asked that students be given more chances for summer work.

L. P. Alford, editor of *Industrial Management*, speaking on The Value of Team Work Among Engineers, pointed out that engineers were aloof, self-centered specialists often regarded as caring for nothing but their narrow professional aims. He urged a nation-wide, all-embracing society expressive of the ideals, purposes and work of all engineers.

John Calder, manager of industrial relations for Swift & Co., Chicago, insisted that the key to many intangible uncertainties in industry is found in the education and training of the foreman, as already carried out in a large number of up-to-date plants. He related the practice of Swift & Co. Their forty classes range from Boston to Portland, Ore., with 50 to 400 foremen in each class, and about 5000 executives in all. Each class is split up into inner groups of from 15 to 20 men, and for each team an executive is selected as team leader. Every class meets as a whole once in two weeks at a lecture, and each class meeting concludes with an open forum in which questions are asked and answered publicly. In most plants, the men have found the training so interesting and their group meetings so helpful that they have effected permanent organizations or clubs, to continue the benefits of the discussion.

Other papers were presented on industrial management in army construction work, industrial safety, fatigue study, cost systems, effect of the industrial engineer on the earning power of industry, and the need of industrial preparedness. About forty companies displayed exhibits which consisted of pictures, charts, and labor-saving devices.

## American Railway Engineering Association

The twenty-first annual convention of the American Railway Engineering Association was held in Chicago from March 16 to 18. Fundamental additions to existing knowledge of the stresses developed in railway track were contained in the second progress report of the committee on stresses in railway track, a joint committee with the American Society of Civil Engineers. It develops from the results obtained in numerous tests with different types of engines that the action of the driving-wheel counterbalance multiplies the static load stresses in the rail. The unbalanced rotating masses at the several drivers subject the rail to excess vertical forces, often larger than the computed effects. In some cases the excess stress chargeable to the unbalance is much more than the static rail stress. With respect to the tie, the nature of the service given by it is defined by measurements of tie bending and distribution of the rail load to the ballast.

The committee on electricity included in its report a study made by a sub-committee of the electrified section of the Chicago, Milwaukee & St. Paul Railway. This experience has demonstrated that the transmission of railway electric power over long distances is efficient, economical and reliable at 110,000 volts, with 3,000 volts on the contact wire. Furthermore, the introduction of electric locomotives equipped with electric brakes has made possible the haulage of heavier trains at higher speeds on heavier grades, such as mountain divisions, and with greater safety and reliability under all climatic conditions. These facts, it was observed, pointed out the way in which hydroelectric power could be still further utilized for the electrification of other railways.

New steel bridge specifications presented by the committee on iron and steel structures were adopted by the convention. Rounded ends for through-plate girders are specified. This is said to be important in the case of derailment of cars. Specific permission for the welding of minor defects in castings is not required.

There was considerable discussion concerning specifications, proposed by the committee on masonry, for billet-steel concrete reinforcement bars specifically prohibiting the use of twisted bars. It was stated that hot-twisted bars are dangerous and that cold-twisted bars give no advantage over plain or deformed bars. The specifications were adopted.

# EFFICIENCY OF NATURAL GAS USED IN DOMESTIC SERVICE

(*Continued from page 288.*)

as in the previous case, the efficiency falls to 15.4 per cent. These efficiencies are represented by a curve in Fig. 3. In many stoves adapted to the use of natural gas, $2\frac{3}{4}$ in. is the distance from burner to the place upon which a vessel is supported. It is apparent not only that there is a provoking loss of time in carrying on heating operations but the gas consumed under such conditions is used very inefficiently.

### Effect of Pressure Variation in Pressure With Mixer Valve Wide Open

Fig. 4 is an efficiency curve obtained when the mixer valve was opened wide and the burner set $2\frac{3}{4}$ in. from the bottom of the vessel. The pressure was varied from 1 in. water head to 7 in., in steps of 1 in. At 7 in. pressure the gas impinged so strongly on the bottom of the vessel that the flame floated around the edges of the vessel. The results are shown in Fig. 4. After the final reading in this set was taken, viz., at 1 in. pressure, another reading was taken under the same flow conditions but with the burner $1\frac{1}{4}$ in. from the kettle. This increased the efficiency from 26.5 to 41.8 per cent. In justice to stove manufacturers it should be stated that their devices are arranged for pressures which vary from 2 to 4 oz., i. e., from $3\frac{1}{2}$ to 7 in. of water, approximately.

A final experiment was made to determine the comparative merits of a granite-ware vessel and an aluminum preserving kettle of the same general size and shape, the general conditions of all the tests being the same. The water equivalent of the containers was not included. The results show a small margin in favor of the aluminum vessel.

As a result of these experiments it may be concluded that efficiencies of 45 per cent or more can be obtained when the burner is set within 2 in. of the vessel, a condition which can be secured easily by adjusting the flame height. Under the varying pressure conditions which now exist, a distance between the limits of 1 in. and $1\frac{1}{2}$ in. is preferable. At this distance the ordinary operations are fairly efficient even at low pressures, while at moderate and high pressures maximum efficiencies may be secured without excessive loss of time.

The author is under obligation to the Public Utilities Commission for the loan of equipment, to the Ohio Experiment Station and to several gentlemen connected with the national gas industry, especially to Mr. S. S. Wyer.

# RECTILINEAR FLIGHT OF AEROPLANES

(*Continued from page 269*)

which he calls Aeroplane-Type, and for which he gives certain numerical values of these four coefficients closely approximating those of the Bréguet army airplane having 50 sq. m. of wing surface.

The main equations of an airplane in horizontal flight are established and an equation is derived indirectly or directly comprising the ten specific coefficients of the airplane, propeller and engine, clearly showing the influence of each of them on the final performance of the airplane. Among other things, it determines through the medium of the specific weight of air the altitude of flight possible with any given incidence; also it determines the ceiling of the airplane in terms of a function involving its specific coefficients.

It also makes possible determining the altitude of flight at which the consumption of the fuel or oil is a minimum, which the author proceeds to do in detail. There are two problems in this connection which can be and are solved practically simultaneously, namely, the altitude at which the plane must fly in order to reduce the consumption of fuel and oil to a minimum, and the cruising radius which may be reasonably expected with airplanes of present construction.

The formulæ derived make it possible to construct a table showing variations of consumption with various angles of incidence and various positions of altitude. Fig. 1 plotted from data of this table shows the variations of fuel and oil consumption at various positions below the ceiling of the plane, which is in this case $Z = 5106$ m. In this figure as abscissæ are plotted the distances in meters of flight at the ceiling, and as ordinates the increases of consumption in percentages with respect to the minimum equal to 0.2997 kg. per hp-hr. for an incidence of $\alpha = 4.6$ deg.

From this curve it appears that the minimum consumption is secured at an altitude only 151 m. below the ceiling. At the ceiling the excess consumption amounts to 2 per cent; at 450 m. below the ceiling to 1 per cent; at 615 m. to 2 per cent and at 1000 m. to 5.1 per cent. These are the limits of altitude within which the pilot should remain in order not to exceed the minimum possible consumption of fuel or oil by 1, 2 or 5 per cent.

A very important problem to the discussion of which the author next proceeds is that of the cruising radii of planes of the present time, because he theoretically establishes the limits attainable in long-distance flights. The conclusion to which he comes is that tests such as the transatlantic flight from Newfoundland to Ireland have shown that a non-stop flight of 3000 km. (1865 miles) is already possible.

He further shows that with the present constructions 5000 km. (3100 miles) are certainly possible and 6000 km. (3725 miles) probable, but that the attainment of a cruising radius of 7000 km. (4350 miles) is quite doubtful.

A somewhat involved formula is given expressing the maximum cruising radius of a plane in terms of a number of variables involving the altitude of flight, fuel and oil consumption, efficiency of propeller, etc.

In the final count it is the ratio $P_0 : P_1$, which is the ratio of total weights of the plane at the beginning and end of the trip, that has most of the influence on the cruising radius. It is easy now to build planes that will lift a load of fuel and oil equal to their own weight, including the weight of the reservoirs, pilot and all of its equipment and accouterments. A lift of 1.5 times the weight of the plane in fuel and oil load is possible, one of twice that weight less certain, and above this quite difficult to accomplish. From these data it would appear that roughly 7000 km. is about the limit that one may hope to attain in the way of a cruising radius under present conditions of aeronautical engineering.

In order to do better than this it will be necessary to build airplanes with a higher fineness ratio or airplanes capable of rising from the ground with a load twice as great as their own weight. In addition to this it will be necessary to provide means making it possible for the pilots to exist comfortably for dozens of hours at altitudes varying from 5000 m. (16,400 ft.) to perhaps 8000 m. (26,250 ft.), which is quite a problem in itself.

# LOCOMOTIVE FEEDWATER HEATING

(*Continued from page 286.*)

if for any reason both are not considered advisable or possible for still further economy.

The feedwater heater offers a solution of the pressing problem of these times, when so many fairly old and small locomotives have outgrown their usefulness because they are not large enough for present-day demands. The feedwater heater will not only increase the capacity of these locomotives, or what might be called their economical operating capacity, at a comparatively low cost and with little change in them, but it will also show a larger percentage of coal saving because of their full loading than would be obtained with present-day larger locomotives.

The feedwater heater offers the peculiar advantage of being of most assistance to the locomotive just at the time when the locomotive needs assistance. It offers its greatest saving in fuel or increase in capacity in the winter time; furthermore these advantages are not affected by reduced steam pressure or superheat, but continue in spite of them and at a proportionately greater rate.

# LIBRARY NOTES AND BOOK REVIEWS

AMERICAN CIVIL ENGINEERS' HANDBOOK. Editor-in-chief, Mansfield Merriman. Fourth edition. John Wiley & Sons, Inc., New York, 1920. Flexible cloth, 4 x 7 in., 1955 pp., tables, $6.

The fourth edition of this well-known reference work follows the plan of the previous editions and is the achievement of a board of eighteen associate editors, under the direction of Professor Merriman. The volume has been thoroughly revised, a collection of mathematical tables included and new sections added on electric railways, irrigation and drainage. Nearly four hundred pages have been added to the work. Because of the comprehensiveness of the book it has been entitled a "Handbook" instead of, as formerly, a "Pocket Book."

AMERICAN MACHINISTS' HANDBOOK. A Reference Book of Machine-Shop and Drawing-Room Data, Methods and Definitions. By Fred H. Colvin and Frank A. Stanley. Third edition, thoroughly revised and enlarged. McGraw-Hill Book Co., Inc., New York, 1920. Flexible cloth, 4 x 7 in., 758 pp., illus., diagrams, tables, $4.

This handbook has been prepared to present in convenient form such data as will be of value to practical men in the various branches of machine work. The present edition has been thoroughly revised. Seventy-seven pages have been added and much other new material included by the elimination of the less important matter from the previous edition.

DESIGN AND CONSTRUCTION OF HEAT ENGINES. By William E. Ninde. First edition. McGraw-Hill Book Co., Inc., New York, 1920. Cloth, 6 x 9 in., 704 pp., illus., diagrams, tables, $6.

The object of this book is to supply in one volume the material most essential to the well-equipped, independent designer of heat engines, and to give this material in the form most convenient for use in class-room and practical work by a separate treatment of the different phases of the subject. The book is the outgrowth of twenty years' experience, and a study of the literature, drawings and practical data. The volume is confined to the steam engine, steam turbine and internal-combustion engine.

THE DESIGN OF SCREW PROPELLERS. With Special Reference to their Adaption for Aircraft. By Henry C. Watts. Longmans, Green & Co., New York, 1920. Cloth, 6 x 9 in., 340 pp., illus., charts, diagrams, plate, tables, $8.

During the war the author was in charge of technical work in connection with propellers for aircraft at the Admiralty and Air Ministry of Great Britain, and many of the propellers used were designed by him or under his supervision. This volume records the results of his experience. It is intended as a guide to practical design and gives slight attention to mathematical theory of the behavior of screw propellers. A chapter on the design of windmills is included.

FLOW AND MEASUREMENT OF AIR AND GASES. By Alec B. Eason. J. B. Lippincott Co., Philadelphia; Charles Griffin & Co., Ltd., London, 1919. Cloth, 6 x 9 in., 252 pp., illus., diagrams, tables, 25 shillings.

The engineering problems investigated in this book arise in connection with pneumatic tubes and compressed-air, gas-lighting and ventilating systems. The author has investigated, by study of the literature and by experiment, the friction of gases and the coefficient of friction in pipes, the question of suitable meters for gas and air, and the working of pneumatic tubes; and has attempted to coördinate the results of various tests and formulas, so that the reason for variations may be appreciated. Full references to the sources of information are given.

GRAPHIC PRODUCTION CONTROL. By C. E. Knoeppel, assisted by various members of the author's firm and staff. The Engineering Magazine Co., New York, 1920. Cloth, 6 x 9 in., 477 pp., illus., diagrams, charts, $6.

This treatise on the use of graphic charts in shop control is intended to provide a complete description of the proper methods of making graphic charts and of applying them to industrial problems. The general principles of graphic control, the preliminaries of its installation, the practical operation of the system, etc., are discussed in detail.

HENDRICKS' COMMERCIAL REGISTER OF THE UNITED STATES FOR BUYERS AND SELLERS. Twenty-eighth annual edition. S. E. Hendricks Co., Inc., New York, 1919-20. Cloth, 8 x 10 in., 2541 pp., $12.50.

This new edition, like its predecessors, is devoted to the electrical, engineering, hardware, iron, mechanical, mill, mining, architectural, quarrying, chemical, railroad, steel, contracting and kindred trades. The firms included are listed alphabetically and by products. A subject index and an index of trade names are also included.

INORGANIC CHEMICAL SYNONYMS and Other Useful Chemical Data. By Elton R. Darling. D. Van Nostrand Co., New York, 1919. Cloth, 4 x 7 in., 100 pp., $1.

The author has collected the various synonyms that have been used in scientific and trade literature to designate the chemicals in common use, and has arranged them so that the substance in question can be accurately identified.

THE LABOR MARKET. By Don D. Lescohier. The Macmillan Co., New York, 1919. Cloth, 5 x 8 in., 338 pp., 9 charts, $2.25.

This work is intended for general readers, employers, legislators, employment officials, college teachers and students of the employment and labor problem. The factors of supply and demand, labor market, machinery and special employment problems are discussed. The author advocates national control of the problem of employment. An extensive bibliography is included.

METALLOGRAPHY. Part I. Principles of Metallography. By Samuel L. Hoyt. First edition. McGraw-Hill Book Co., Inc., New York, 1920. Cloth, 6 x 9 in., 256 pp., illus., diagrams, tables, $3.

This volume, the first of a series of three based on the author's lectures at the University of Minnesota, deals with general principles and with some of the more important methods used in general investigations in the metallographic laboratory. Future volumes will discuss the metallography of the metals and alloys and the applications of metallography to the metallurgical and engineering industries.

MOTOR VEHICLE ENGINEERING. Engines (for Automobiles, Trucks and Tractors). By Ethelbert Favary. Second edition. McGraw-Hill Book Co., Inc., New York, 1920. Cloth, 6 x 9 in., 333 pp., illus., plates, tables, $3.50.

The author states that many chapters of this edition have been entirely rewritten, that the practical data have been brought up to date and that the work has been generally revised. The book treats of automobile engines and is intended to give a concise, simple statement of the every-day information needed by automotive engineers.

THE ORGANIZATION OF INDUSTRIAL SCIENTIFIC RESEARCH. By C. E. Kenneth Mees. First edition. McGraw-Hill Book Co., Inc., New York, 1920. Cloth, 6 x 8 in., 175 pp., $2.

Contents: Types of research laboratories; coöperative laboratories; position of the research laboratory in an industrial organization; internal organization of industrial research laboratories; staff of a research laboratory; building and equipment of the laboratory; direction of the work; design of a research laboratory for a specific industry.

This volume is a contribution to the current discussion of the relation of scientific research to industry. The author is concerned with a study of the best methods of organizing research work for industrial purposes and of the conditions under which such work should be conducted, and has made an effort to give definite suggestions upon these points. The book is intended for those who plan to undertake research work rather than as an exposition of its theoretical advantages.